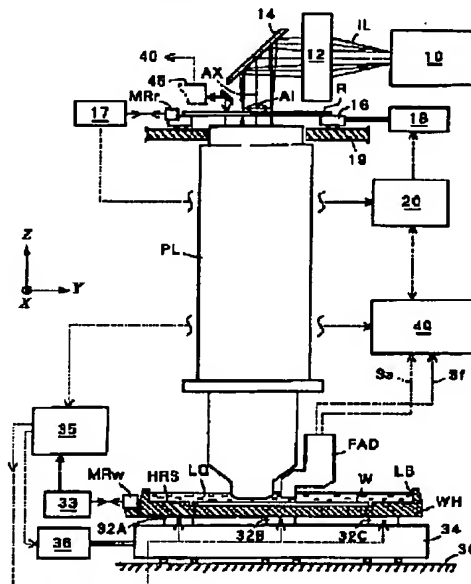(54) **IMMERSION ALIGNER**

(57) Abstract:

PROBLEM TO BE SOLVED: To provide an immersion aligner which does not cause the deterioration of its image forming performance.

SOLUTION: An immersion aligner which is provided with a projection optical system PL which transfers a pattern Pa drawn on a reticle R to the surface of a wafer W and print-transfers the pattern Pa, and in which at least part of the working distance L between the lens surface Pe of the optical system PL closest to the wafer W and the wafer W, is filled up with a liquid LQ which transmits exposing light IL is constituted so that the working distance L may meet a relation, $L \leq \lambda/(0.3 \times |N|)$ (where, $\lambda$ and N (1/°C) respectively represent the wavelength of the light IL and the temperature coefficient of the refractive index of the liquid IQ). In addition, the liquid LQ is prepared by adding an additive which reduces the surface tension of pure water or increases the interface activity of the pure water to the pure water.

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(54) [Title of the Invention] IMMERSION ALIGNEREXPOSURE APPARATUS

(57) [Abstract]

[Problem] To provide an immersion alignerexposure apparatus that does not cause the degradation of its image forming performance.

[Solution] An immersion alignerexposure apparatus has a projection optical system PL for transfer-printingexposure-transferring of a pattern Pa, written on a reticle R, onto a wafer W. In the immersion alignerexposure apparatus, at least part of working distance L between the wafer and the lens surface Pe closest to the wafer in the projection optical system is filled with a liquid LQ through which exposure light IL passes. The immersion alignerexposure apparatus is so constructed that the working distance will meet the following relation: $L \leq \lambda/(0.3 \times |N|)$, where L is the length of the working distance, $\lambda$ is the wavelength of the exposure light IL, and N (1/°C) is the temperature coefficient of the refractive index of the liquid LQ. In addition, pure water with an additive added in it to reduce the surface tension of the pure water or enhance the interface activity of the pure water is used as the liquid LQ.

[Claims]

[Claim 1]  An immersion alignerexposure apparatus, which has a projection optical system for transfer-printingexposure transferring of a pattern, written on a reticle, onto a wafer, and in which at least part of working distance between the wafer and the lens surface closest to the wafer in the projection optical system is filled with a liquid through which exposure light passes, the immersion alignerexposure apparatus characterized in that the working distance will meet the following relation:

$$L \leq \lambda / (0.3 \times |N|),$$

where L is the length of the working distance, $\lambda$ is the wavelength of the exposure light IL, and N (1/°C) is the temperature coefficient of the refractive index of the liquid LQ.

[Claim 2]  An immersion alignerexposure apparatus, which has a projection optical system for transfer-printingexposure-transferring of a pattern, written on a reticle, onto a wafer, and in which at least part of working distance between the wafer and the lens surface closest to the wafer in the projection optical system is filled with a liquid through which exposure light passes, the immersion alignerexposure apparatus characterized in that pure water with an additive added in it to reduce the surface tension of the pure water or enhance the interface activity of the pure water is used as the liquid.

[Claim 3]  The immersion alignerexposure apparatus according

to claim 1 or 2, wherein the length L of the working distance is 2 mm or less.

[Claim 4] The immersion alignerexposure apparatus according to claim 1, 2, or 3, wherein the reticle and the wafer are so arranged that they can be scanned synchronously at a constant speed with a speed ratio corresponding to the magnification of the projection optical system.

[Claim 5] The immersion alignerexposure apparatus according to claim 1, 2, 3, or 4, wherein light in the ultraviolet band is used as the exposure light.

[Claim 6] The immersion alignerexposure apparatus according to claim 1, 2, 3, 4 or 5, wherein the optical surface of the front optical element closest to the wafer side in the projection optical system is formed flat, the lower end face of a lens barrel holding the front optical element is formed flush with the optical surface, and the outer circumferential face at the lower end of the lens barrel is chamfered.

[Claim 7] The immersion alignerexposure apparatus according to claim 6, wherein the front optical element is a parallel flat plate.

[Claim 8] The immersion alignerexposure apparatus according to any one of claims 1 through 7, wherein the wafer is held by a holder table, a wall is provided around the perimeter of the upper face of the holder table so that the liquid can be filled in the working distance, a liquid supply unit is provided inside the holder table so that the liquid can

be supplied and recovered, and thermoregulators are provided in both the holder table and the liquid supply unit.

[Claim 9] The immersion alignerexposure apparatus according to any one of claims 1 through 7, wherein the wafer is held by a wafer chuck, a wall is provided around the perimeter of the upper face of the wafer chuck so that the liquid can be filled in the working distance, at least three pins are provided through the wafer chuck, and an elevation driving device is provided to enable the pins to lift up the wafer from the wafer chuck.

[Claim 10] The immersion alignerexposure apparatus according to any one of claims 1 through 7, wherein the wafer is held by a wafer chuck, a wall is provided around the perimeter of the upper face of the wafer chuck so that the liquid can be filled in the working distance, at least three pins are provided through the wafer chuck, and an elevation driving device is so provided that the upper end of the wall of the wafer chuck can be lower than the lower end of the projection optical system.

[Claim 11] The immersion alignerexposure apparatus according to any one of claims 1 through 10, wherein a liquid sealing door is provided in a portion of the wall to freely open or close in order to avoid interference with the lower end part of the projection optical system.

[Claim 12] The immersion alignerexposure apparatus according to any one of claims 1 through 11, wherein a

mirror for an interferometer is attached to the side face
of the projection optical system, and protection means is
provided for separating a light beam incident on and
reflected from the mirror from vapor generated from the
liquid.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]  The present invention relates to
an alignerexposure apparatus for printing a pattern,
written on a reticle, onto a wafer through a projection
optical system, and particularly to an immersion
alignerexposure apparatus.

[0002]

[Description of the Prior Art]  Spacingclearance between the
last or front lens surface of an optical system and an
image surface is called working distance.  The working
distance of a projection optical system in the conventional
alignerexposure apparatus or exposure apparatus is filled
with air.  It is common practice to take a working distance
of 10mm or more for some reason such as to include an
autofocus optical system.  On the other hand, with ever
increasing demand for finer patterns to be transferred to a
wafer, it is necessary to make the exposure wavelength
shorter or increase the numerical aperture.  However, since
there are restrictions on the types of glass materials that
allow light having a short wavelength to pass through,
immersion type alignerexposure apparatus have been proposed

in which the working distance is filled with a liquid to increase the numerical aperture and hence make the exposed pattern finer.

[0003] The immersion type alignerexposure apparatus could cause an uneven distribution of refractive indexes due to a temperature distribution of the liquid interposed in the working distance. Therefore, the following techniques have been proposed as measures against the degradation of image forming performance caused by liquid temperature changes: namely, (A) a technique for stabilizing temperature through a liquid temperature stabilizing mechanism as disclosed in FIG. 3 of US Patent No. 4,346,164,or for making temperature uniform using a vibration-agitator mechanism as disclosed in Japanese Patent Laid-Open No. 06-124873; and (B) a technique, as also disclosed in Japanese Patent Laid-Open No. 6-124873, for measuring the temperature or refractive index of the liquid using a liquid temperature monitoring mechanism to feed it back for temperature control.

[0004]

[Problem to be Solved by the Invention] However, since there has been no discussion regarding the degree of temperature stabilization from a practical perspective to implement the technique (A), this technique actually requires high accuracy of temperature control, as will be described below, which is far from practical. On the other hand, it is also hard to say that the technique (B) is effective because what most affects the image forming

performance is the unevenness of temperature. Thus, no conventional techniques for immersion alignerexposure apparatus make direct reference to the restrictions on the optical parameters of the projection optical system such as the working distance, and the immersion technology hardly allows for its peculiarities at present. It is therefore an object of the present invention to provide an immersion alignerexposure apparatus, which makes it easy to control the temperature of a liquid filled in the working distance to prevent the degradation of image forming performance.
[0005]

[Means for Solving the Problem] The present invention has been made to solve the above-mentioned problem, that is, to provide an immersion alignerexposure apparatus, which has a projection optical system for transfer-printingexposure-transferring of a pattern, written on a reticle, onto a wafer, and in which at least part of working distance between the wafer and the lens surface closest to the wafer in the projection optical system is filled with a liquid through which exposure light passes, the immersion alignerexposure apparatus characterized in that the working distance meets the following relation:

$L \leq \lambda / (0.3 \times |N|)$

where L is the length of the working distance, $\lambda$ is the wavelength of the exposure light, and N (1/°C) is the temperature coefficient of the refractive index of the liquid. The immersion alignerexposure apparatus is also

characterized in that the liquid used is pure water with an additive added in it to reduce the surface tension of the pure water or enhance the interface activity of the pure water.

[0006] The following describes the operation of the present invention. If the distance from the glass surface at the tip end of the projection optical system to an imaging plane, that is, if the working distance is L, the width of a temperature distribution of the medium filled in the working distance L is $\Delta T$, the aberration of the imaging wavefront caused by the temperature distribution $\Delta T$ is $\Delta F$, and the temperature coefficient of the refractive index of the liquid is N, the following expression (1) is approximately established:

$\Delta F = L \times |N| \times \Delta T$ ...(1)

[0007] It is assumed that a temperature distribution of about 0.01°C exists in the temperature distribution $\Delta T$ of the medium even though temperature is controlled by all means in order to keep it uniform. Therefore, at least the following imaging wavefront aberration $\Delta F$ is considered to exist:

$\Delta F = L \times |N| \times 0.01°C$ ...(1a)

where N is a value representing the temperature coefficient of the refractive index in a unit of 1/°C.

[0008] The value N of the temperature coefficient of the refractive index varies greatly between liquid and air. For example, for air, $N = -9 \times 10^{-7}$/°C, and for water, $N - 8 \times 10^{-5}$/°C,

that is, the difference is almost 100 times. In general, the working distance L of a projection optical system in a reduction projection alignerexposure apparatus is L>10 nm. Even if L=10 nm, the imaging wavefront aberration $\Delta F$ becomes as follows:

For air, $\Delta F=10mm\times|-9\times10^{-7}/°C|\times0.01/°C=0.09$ nm

For water, $\Delta F=10mm\times|-8\times10^{-5}/°C|\times0.01/°C=8.0$ nm

[0009] Therefore, it is preferable that the imaging wavefront aberration $\Delta F$ be generally equal to or less than 1/30 of the exposure wavelength $\lambda$, that is, it should meet the following relation:

$\Delta F\leq\lambda/30$     ...(2)

For example, when an ArF excimer laser having a wavelength of 193 nm is used as the exposure light, $\Delta F<6.4$ nm is desirable. In the case of using water as the medium filled in the working distance, if the working distance L is L>10 mm as in the conventional, the generation of imaging wavefront aberration due to the temperature distribution of the medium is too much, resulting in practical difficulties.

[0010] From the expressions (1a) and (2), the following expression is obtained:

$L\leq\lambda/(0.3\times|N|)$     ...(3)

Therefore, if the expression (3) is satisfied, an immersion alignerexposure apparatus equipped with a projection optical system that reduces the wavefront aberration caused by the temperature distribution in the immersion liquid to 1/30 or less of the exposure wavelength under the

conditions of feasible temperature stability (temperature distribution) can be obtained. As described above, according to the present invention, an upper limit is set on the length of an optical path to mitigate the requirements for a temperature distribution by paying attention to the fact that the amount of wavefront aberration generated when the exposure light passes through the medium having the temperature distribution depends on the product of the amount of temperature distribution and the length of the optical path in the medium. This makes it possible to put an immersion alignerexposure apparatus to practical use at a feasible level of temperature control of the immersion liquid.

[0011]

[Embodiments of the Invention] The following describes some preferred embodiments of the present invention.

[0012]

[Description of First Embodiment] FIG. 1 shows the overall structure of a projection exposure apparatus or alignerexposure apparatus, according to a first embodiment of the present invention. Here, the projection alignerexposure apparatus is a lens-scanning type projection alignerexposure apparatus, which scans a reticle R and a semiconductor wafer W relative to a reduction projection lens system PL while projecting a circuit pattern on the reticle R to the wafer W through the projection lens system PL having circular image fields

telecentrically formed on both the object side and the image side.  In FIG. 1, an illumination system 10 includes an ArF excimer-laser light source (not shown) emitting pulsed light having a wavelength of 193 nm, a beam expander (not shown) for shaping the cross section of the pulsed light from the light source, an optical integrator (not shown) such as a fly-eye lens for producing a secondary light-source image (a collection of plural point sources) from the shaped pulsed light incident on it, a condenser lens system (not shown) for turning the pulsed light from the secondary light-source image into pulsed illumination light having a uniform luminance distribution, a reticle blind (illumination field stop, not shown) for shaping the pulsed illumination light into a rectangular shape elongated in a direction (X direction) perpendicular to the scanning direction (Y direction) during scanning exposure, and a relay optical system (not shown) that cooperates with a condenser lens system 12 and a mirror 14 shown in FIG. 1 to focus the pulsed light IL from the rectangular opening of the reticle blind on an illuminated area AI of a slit or rectangular shape on the reticle R.

[0013]  The reticle R is held by vacuum suction (otherwise, by electrostatic suction or machine-rivetingmechanical-fastening) on a reticle stage 16 capable of moving with a large stroke in a one-dimensional direction at a constant speed during scanning exposure.  In FIG. 1, the reticle stage 16 is guided to move from side to side (in the Y

direction in FIG. 1) on a column structure 19 of the apparatus body, while it is also guided to move in a direction (X direction) perpendicular to the paper surface of FIG. 1. The coordinate position and minute amount of rotation of the reticle stage 16 on the XY plane are measured sequentially by a laser interferometer system 17 projecting a laser beam to a moving mirror (plane mirror or corner mirror) MRr attached to a portion of the reticle stage 16 and receiving a reflected beam from the moving mirror MRr. Then, a reticle stage controller 20 controls a motor 18, such as a linear motor or voice coil motor, for driving the reticle stage 16 based on the XY coordinate position measured by the interferometer system 17 to control the movement of the reticle stage 16 in both the scanning and non-scanning directions.

[0014] When part of the circuit pattern area on the reticle R is illuminated by the rectangular-shaped pulsed illumination light IL projected through the condenser lens system 12 and the mirror 14, an imaging beam from the pattern in the illuminated area AI is projected and focused on a photosensitive resist layer coated on the surface of the wafer W through the reduction projection lens system PL with a reduction ratio of 1/4. The projection lens system PL is so arranged that its optical axis AX passes through the central points of the circular image fields and is concentric with the optical axes of the illumination system 10 and the condenser lens system 12, respectively. The

projection lens system PL consists of a plurality of lens elements made of two types of glass materials, quartz and fluorite, having high transmittance with respect to ultraviolet light having a wavelength of 193 nm. Fluorite is used primarily to form lens elements having positive power. Further, the air in a lens barrel in which the plurality of lens elements of the projection lens system PL are retained is replaced with nitrogen gas to avoid the absorption by oxygen of the pulsed illumination light having the wavelength of 193nm. The nitrogen-gas replacement is also provided for the optical path from the inside of the illumination system 10 up to the condenser lens system 12 (or the mirror 14) in the same manner.

[0015] The wafer W is held on a holder table WH that draws the back side of the wafer W by suction. A wall LB is provided at a constant height around the entire perimeter of the holder table WH, and the liquid LQ is filled inside the wall LB up to a predetermined depth. The wafer W is held by vacuum suction in a depressed portion on the inner bottom of the holder table WH. Further, an annular auxiliary plate HRS is provided around the inner bottom of the holder table WH to surround the perimeter of the wafer W with a predetermined clearance width. The height of the surface of the auxiliary plate HRS is defined to be approximately equal to the height of the surface of a standard type of wafer W drawn by suction on the holder table WH.

[0016] The auxiliary plate HRS is primarily used as an alternative focus detection surface when the detection point of a focus-leveling sensor is located on the outside of the outer edge of the wafer W. The auxiliary plate HRS can also be used for calibration of an alignment sensor used for relative alignment between a shot area on the wafer W and the circuit pattern on the reticle R, and for calibration of the focus-leveling sensor used when the shot area is scanned and exposed. However, it is preferable to use a dedicated fiducial mark plate provided separately from the auxiliary plate HRS. In this case, the fiducial mark plate is also mounted on the holder table WH in an immersed state to have substantially the same height as the image projection surface of the projection lens system PL, so that the alignment sensor detects various fiducial marks formed on the fiducial mark plate in the immersed state. An example of methods for calibration of system offsets of the focus sensor using the fiducial mark plate on the table is disclosed, for example, in US Patent No. 4,650,983, and an example of calibration methods for various alignment sensors is disclosed, for example, in US Patent No. 5,243,195.

[0017] In the embodiment, as shown in FIG. 1, since the tip end of the projection lens system PL is immersed in the liquid LQ, the projection lens system PL is designed to render at least its tip end waterproof in order to prevent the liquid from leaking into the lens barrel. The lower

face (opposite face to the wafer W) of the front lens element of the projection lens system PL is machined in the shape of a flat surface or a convex surface having an extremely large curvature radius so that the liquid can flow smoothly between the lower face of the lens element and the surface of the wafer W during scanning exposure. Further, in the embodiment, the projection lens system PL is designed, as will be described in detail later, to form its best imaging plane (reticle conjugate plane) in the immersed state at a position about 2-1 mm from the lower face of the front lens element. Therefore, the thickness of the liquid layer formed between the lower face of the front lens element and the surface of the wafer W is also about 2-1 mm, so that not only can the accuracy of temperature control to adjust the temperature of the liquid LQ be relaxed, but an uneven temperature distribution in the liquid layer can also be prevented.

[0018] The holder table WH is mounted on an XY stage 34 in such a manner to enable translational movements (including rough and fine movements in the embodiment) in the Z direction along the optical axis AX of the projection lens PL and fine tilt movements with respect to the XY plane perpendicular to the optical axis AX. The XY stage 34 moves two-dimensionally in the X and Y directions on a base 30. The holder table WH is mounted on the XY stage 34 through three Z-actuators 32A, 32B, and 32C. Each of the actuators 32A-C is a mechanism consisting, for example, of a

combination of a piezoelastic element, a voice coil motor, a DC motor, and a lift cam. When the three Z-actuators are driven in the Z direction by the same amount, the holder table WH can be translated in parallel in the Z direction (focus direction), while when the three Z-actuators is driven in the Z direction by amounts different from one another, the tilt direction and amount of the holder table WH can be adjusted.

[0019] The two-dimensional movement of the XY stage 34 is caused by a drive motor 36, such as a DC motor for rotating a feed screw or a linear motor for generating thrust in a non-contact manner. The drive motor 36 is controlled by a wafer stage controller 35 receiving measured coordinate positions from a laser interferometer 33 for measuring each of X- and Y-positional changes of the reflection surface of a moving mirror MRw fixed to an edge portion of the holder table WH. The overall structure of the XY stage 34 using a linear motor as the drive motor 36 is disclosed, for example, in Japanese Patent Laid-Open No. 8-233964.

[0020] In the embodiment, since the working distance of the projection lens PL is so small that the liquid LQ will be filled in a narrow space of about 2-1 mm between the front lens element of the projection lens PL and the wafer W, it is difficult for an obliquely-incident type focus sensor to project a flood projection beam of light obliquely from above onto the wafer surface corresponding to the projection field of the projection lens system PL.

Therefore, in the embodiment, a focus alignment sensor FAD,
including an off-axis type focus leveling detection system
(having no focus detection point within the projection
field of the projection lens system PL) and a mark
detection system for detecting alignment marks on the wafer
W in an off-axis manner, is arranged as shown in FIG. 1
around the lower end part of the lens barrel of the
projection lens system PL.

[0021]  The lower faces of an optical elements (lens, glass
plate, prism, etc.) attached to the tip of the focus
alignment sensor FAD are is placed in the liquid LQ, and an
alignment illumination beam and a focus detection beam are
emitted from the optical elements to illuminate the surface
of the wafer W (or the auxiliary plate HRS) through the
liquid LQ.  The focus leveling detection system outputs a
focus signal Sf corresponding to an error in the position
of the surface of the wafer W relative to the best imaging
plane.  The mark detection system analyzes a photoelectric
signal corresponding to the optical characteristics of each
mark on the wafer W to output an alignment signal Sa
representing the XY position of the mark or the amount of
displacement from the position.

[0022]  The focus signal Sf and the alignment signal Sa are
sent to a main controller 40.  Based on the focus signal Sf,
the main controller 40 sends the wafer stage controller 35
driving information best suited to each of the three Z-
actuators 32A, B, C.  The wafer stage controller 35 controls

each of the three Z-actuators 32A, B, C to make focus and tilt adjustments to an actually projected area on the wafer W.

[0023] The main controller 40 also manages the coordinate position of the XY stage 34 based on the alignment signal Sa to align the relative position of the reticle R and the wafer W. Further, when each shot area on the wafer W is scanned and exposed, the main controller 40 performs synchronous control of the reticle stage controller 20 and wafer stage controller 35 so that the reticle R and the wafer W will move in the Y direction at a constant speed with a speed ratio corresponding to the projection magnification of the projection lens system PL.

[0024] Note that, although the focus alignment sensor FAD is provided in FIG. 1 in one location around the tip end of the projection lens system PL, it is preferable that four focus alignment sensors FAD be provided, two in the Y direction and two in the X direction, across the tip end of the projection lens system PL. In addition, a TTR (Through-The-Reticle) type alignment sensor 45 is provided above the reticle R in FIG. 1 to detect alignment marks formed around at the periphery of the reticle R and alignment marks on the wafer W (or fiducial marks on the fiducial mark plate) simultaneously through the projection lens system PL and hence to measure the displacement between the reticle R and the wafer W with a high degree of precision. A measured displacement signal is then sent from the TTR alignment

sensor 45 to the main controller 40 for use in positioning the reticle stage 16 and the XY stage 34.

[0025] The exposure apparatus or aligner in FIG. 1 performs scanning exposure while moving the XY stage 34 in the Y direction at a constant speed. The following describes the schedule of scan and step movements of the reticle R and the wafer W during the scanning exposure with reference to FIG. 2. In FIG. 2, a front lens group system LGa and a rear lens group system LGb are representative of the projection lens system PL in FIG. 1, and a projection pupil Ep of the projection lens system PL exists between the front lens group system LGa and the rear lens group system LGb. On the reticle R shown in FIG. 2, a circuit pattern area Pa having a diagonal length longer than the diameter of the circular image field on the object side of the projection lens system PL is formed on the inside of a light-shielding zone SB.

[0026] The area Pa on the reticle R is scanned and exposed to a corresponding shot area SAa on the wafer W by scan-moving the reticle R, for example, in a negative direction along the Y axis at a constant speed Vr while scan-moving the wafer W in a positive direction along the Y axis at a constant speed Vw. In this case, as shown in FIG. 2, the area AI of the pulsed illumination light IL illuminating the reticle R is formed in the shape of a slit or rectangle elongated in parallel with the X direction in the area Pa, with both ends in the X direction located on the light-

shielding zone SB.

[0027] A part of the pattern included in the pulsed light illuminated area AI inside the area Pa on the reticle R is formed as an image SI in a corresponding position inside the shot area SAa on the wafer W through the projection lens system PL (the lens systems LGa, LGb). After completion of relative scanning of the pattern area Pa on the reticle R and the shot area SAa on the wafer W, the wafer W is step-moved by a given amount in the Y direction so that it will come to a scanning start position, for example, to a shot area SAb next to the shot area SAa. During this step-movement, the emission of the pulsed illumination light IL is interrupted. Then, the reticle R is moved in the positive direction along the Y axis with respect to the pulsed light illuminated area AI at the constant speed Vr so that another the pattern image in the area Pa on the reticle R will be scanned and exposed to the corresponding shot area SAb on the wafer W while moving the wafer W in the negative direction along the Y axis with respect to the projected image SI at the constant speed Vw, thereby forming an electronic circuit pattern image on the shot area SAb. An example of techniques using pulsed light from an excimer-laser light source for scanning exposure is disclosed, for example, in US Patent No. 4,924,257.

[0028] In the projection alignerexposure apparatus shown in FIGS. 1 and 2, when the diagonal length of the circuit pattern area on the reticle R is smaller than the diameter

of the circular image field of the projection lens system
PL, the opening shape or size of the reticle blind in the
illumination system 10 can be so changed that the shape of
the illuminated area AI will coincide with that of the
circuit pattern area, enabling the use of the apparatus of
FIG. 1 as a step-and-repeat stepper.  In this case, the
reticle stage 16 and the XY stage 34 stay still relative to
each other during exposure of the shot area on the wafer W.
However, if the wafer W moves slightly during the exposure,
the slight movement can be measured by the laser
interferometer system 33.  The reticle stage 16 is
controlled and moved slightly in order to perform a
tracking correction on the reticle R side so that to
control the reticle R side to move the reticle stage 16
slightly in order to compensate for the slight displacement
of the wafer W with respect to the projection lens system
PL is compensated.  Further, when the shape or size of the
reticle blind is changed, a zoom lens system may be so
provided that the pulsed light coming from the light source
and reaching the reticle blind will converge on a region
corresponding to the adjusted opening size in response to
the change in the shape or size of the reticle blind.
[0029]  As apparent from FIG. 2, since the area of the
projected image SI is assumed to have a slit or rectangular
shape elongated in the X direction, the embodiment is
configured to make the tilt adjustment during scanning
exposure exclusively in a rotational direction around the Y

axis, that is, only the rolling direction with respect to the direction of scanning exposure. Of course, if the width of the area of the projected image SI in the scanning direction is large enough to require consideration of the flatness of the wafer surface in the scanning direction, the tilt adjustment will be made in a rotational direction around the X axis, that is, the pitching direction, during scanning exposure.

[0030] The state of the liquid LQ in the holder table WH that is a characteristic feature of the alignerexposure apparatus according to the embodiment will be described below with reference to FIG. 3. FIG. 3 is a partially sectional view from the tip end of the projection lens system PL to the holder table WH. A positive lens element LE1 whose lower face Pe is flat and upper face is convex is fixed at the tip of the projection lens system PL inside the lens barrel. The lower face Pe of the lens element LE1 is so finished that the lower face Pe will be flush with the end face of the tip end of the metallic part of the lens barrel (flush surface finishing), preventing the flow of the liquid LQ from becoming turbulent. An outer corner portion 114, which is a portion to be immersed in the liquid LQ at the tip end of the lens barrel of the projection lens system PL, is chamfered, for example, to have a large curvature as shown in FIG. 3, in order reduce resistance against the flow of the liquid LQ and hence to prevent the generation of an unnecessary vortex or

turbulent flow. Further, a plurality of protruding suction faces 113 are formed in a central portion of the inner bottom of the holder table WH to draw the back face of the wafer W by vacuum suction. Specifically, these suction faces 113 assume the shape of an annular zone consisting of a plurality of annular land portions having about 1 mm in height and concentrically formed with a predetermined pitch in the direction of the radius of the wafer W. Then, a groove is cut at the center of each of the annular land portions, and each of the grooves is connected to piping 112 inside the table WH, and to a vacuum source for vacuum suction.

[0031]  In the embodiment, as shown in FIG. 3, the spacing or distance L between the lower face Pe of the lens element LE1 at the tip end of the projection lens system PL and the surface of the wafer W (or the auxiliary plate HRS) is set in the range of about 2-1 mm for the best focus state. Therefore, the depth Hq of the liquid LQ to be filled in the holder table WH can be just two, three, or more times the distance L, and hence the height of the wall LB provided around the holder table WH can be just several to ten mm. Thus, in the embodiment, since the distance L as the working distance of the projection lens system PL is set very small, the total amount of liquid LQ to be filled in the holder table WH can be reduced, thereby making temperature control easy.

[0032]  In the embodiment, pure water easy to obtain and

handle is used for the liquid LQ. However, note that a slight percentage of aliphatic additive (liquid), which does not dissolve the resist layer of the wafer W and the influence of which on the optical coating of the lower face Pe of the lens element can be ignored, is added to the pure water to not only reduce the surface tension of the pure water but to enhance the interface activity of the pure water. Methyl alcohol or the like having a refractive index approximately equal to that of the pure water is preferably used as the additive. In such a case, even if the methyl alcohol component in the pure water evaporates to vary its concentration, the total change in the refractive index of the liquid LQ can be minimized.

[0033] The temperature of the liquid LQ is controlled for a target temperature with a constant degree of accuracy. The accuracy of controlling temperature in a relatively easy manner at present is about $\pm 0.01°C$. Based on such temperature-control accuracy, the following considers a realistic immersion projection method. In general, the temperature coefficient $N_a$ of the refractive index of air is about $-9 \times 10^{-7}/°C$, while the temperature coefficient $N_q$ of the refractive index of water is about $-8 \times 10^{-5}/°C$. In other words, the temperature coefficient $N_q$ of the refractive index of water is about two orders of magnitude larger than that of air. On the other hand, if the working distance is L, the amount of imaging wavefront aberration $\Delta F$ caused by the amount of temperature change (temperature unevenness)

ΔT in the medium filled in the working distance L is approximately represented as follows:

$\Delta F = L \cdot |N| \cdot \Delta T$

[0034] Here, if normal projection exposure is carried out without the application of an immersion projection method, the amount of wavefront aberration $\Delta F_{air}$ under such conditions that the working distance L is 10mm and the amount of temperature change ΔT is 0.01°C is as follows:

$\Delta F_{air} = L \cdot |Na| \cdot \Delta T \approx 0.09$ nm

On the other hand, the amount of wavefront aberration $\Delta F_{lq}$ in the case of applying the immersion projection method is as follows:

$\Delta F_{lq} = L \cdot |N_q| \cdot \Delta T \approx 8$ nm

[0035] In general, it is desirable that the amount of wavefront aberration be about 1/30 through 1/50-1/100 of the wavelength λ used. Therefore, in the case of using the ArF excimer laser, the maximum allowable amount of wavefront aberration $\Delta F_{max}$ is defined in the range of 6.43 through 3.86-1.93 nm corresponding to 1/30 through 1/50-1/100 of the wavelength λ generally used, and preferably 1.93 nm or below at 1/100 of the wavelength λ. The heat conductivities of air and water at 0°C are 0.0241 W/mK and 0.561 W/mK, respectively. In other words, water is better heat conductor than air, so that the temperature unevenness in the optical path formed in the water can be reduced compared to that in the air, thereby reducing the fluctuation in the refractive index in the liquid. However,

as shown in the expression (3), if the working distance L is about 10 mm, the amount of wavefront aberration $\Delta F_{1q}$ generated is far beyond the allowable amount of wavefront aberration $\Delta F_{max}$ even if the amount of temperature change $\Delta T$ is 0.01°C.

[0036] It follows from the above consideration that the relationship between the amount of temperature change $\Delta T$ after taking into account the amount of allowable wavefront aberration $\Delta F_{max}$ and the working distance L is from $\Delta F_{max}=\lambda/30 \geq L \cdot |N_q| \cdot \Delta T$ to $\Delta F_{max}=\lambda/100 \geq L \cdot |N_q| \cdot \Delta T$. Assuming that the amount of temperature change $\Delta T$ is 0.01°C, the wavelength $\lambda$ is 193nm, and the amount of change $N_q$ in the refractive index of the liquid LQ is $-8 \times 10^{-5}$/°C, the required working distance (thickness of the liquid layer) L is from 8 mm to 2.4 mm or less. It is desirable that the working distance L be smaller than 2 mm as long as the liquid LQ flows smoothly in the working distance L. Since the embodiment is configured as mentioned above, not only can the temperature control of the liquid LQ be made easy, but the degradation of the projected image induced by a change in wavefront aberration due to a temperature change in the liquid layer can also be prevented, making possible projection exposure of a pattern on the reticle R with an extremely high resolution.

[0037]

[Description of Second Embodiment] Referring next to FIG. 4, a second embodiment of the present invention will be

described. This embodiment shows a temperature control method for the liquid LQ, which is also applicable to the first embodiment, and a method of dealing with the liquid LQ at the time of changing the wafer W. Therefore, components in FIG. 4 common to those in FIGS. 1 and 3 are given the same reference numerals and symbols. In FIG. 4, a plurality of suction faces 113 are formed in a wafer loading portion as a circular depressed portion on the inner bottom of the holder table WH. Then an annular groove 51 used for supply and discharge of the liquid LQ is formed around the circular wafer loading portion. Part of the groove 51 communicates with an external pipe 53 through a passage 52 formed inside the table WH. Further, thermoregulators 50A, 50B such as Peltier elements are embedded directly below the wafer loading portion and the auxiliary plate HRS inside the holder table WH, and temperature sensors are placed in position (preferably at plural positions) on the holder table WH to detect the temperature of the liquid LQ precisely. The thermoregulators 50A, 50B are controlled by a controller 60 in such a manner that the temperature of the liquid LQ detected by the temperature sensors 55 will be kept at a fixed constant value.

[0038] On the other hand, the pipe 53 is connected to a liquid supply unit 64 and a drainage pump 66 through a selector valve 62. The selector valve 62 switches over between a flow path for supplying the liquid LQ from the

liquid supply unit 64 to the pipe 53 and a flow path for returning the liquid LQ from the pipe 53 to the supply unit 64 through the drainage pump 66 in response to an instruction from the controller 60. Inside the supply unit 64, a reserve tank (not shown) capable of reserving the total amount of liquid LQ on the holder table WH, a pump 64A for supplying the liquid LQ from the tank, and a temperature controller 64B for keeping the liquid LQ in the tank including the pump 64A at a constant temperature are provided. In the above-mentioned structure, the operation of the valve 62, the pump 64A, the temperature controller 64B, and the drainage pump 66 are centrally controlled by the controller 60.

[0039] In such a structure, when the wafer W is fed carried to the wafer loading portion of the holder table WH and loaded on the plural suction faces 113 in a pre-aligned state, the wafer is fixed under a reduced pressure through the vacuum suction piping 112 shown in FIG. 3. During this operation, the thermoregulators 50A, 50B continue to be controlled at a target temperature. Then, upon completion of vacuum suction of the wafer W, the selector valve 62 is moved from a closed position to the supply unit 64 side to actuate the pump 64A to fill the temperature-controlled liquid LQ to the inside of the wall LB of the holder table WH by a given amount through the pipe 53, the passage 52, and the groove 51. After that, the selector valve 62 returns to the closed position. Once the exposure of the

wafer W is completed, the selector valve 62 is moved from the closed position to the drainage pump 66 side to actuate the drainage pump 66 to return the liquid LQ on the table WH to the reserve tank in the supply unit 64 through the groove 51 and the pipe 53. The temperature of the liquid LQ returned to the tank is controlled precisely by the temperature controller 64B based on a detection signal from a temperature sensor provided in the reserve tank until the next wafer is ready.

[0040] Thus, according to the embodiment, the temperature of the liquid LQ during immersion exposure is controlled by the thermoregulators 50A, 50B in the holder table WH, while the liquid LQ is recovered into the supply unit 64 during wafer change so that the temperature of the liquid LQ will be controlled in the supply unit 64. This structure has the advantages of making possible wafer change in air and preventing a big temperature change in the liquid LQ. Further, according to the embodiment, even if the temperature of the liquid LQ filled in the holder table WH after wafer change is deviated slightly (e.g., about 0.5°C) from a set temperature, it can reach the set temperature in a relatively short time because the depth of the liquid layer $H_q$ (see FIG. 3) is shallow on the whole, thereby also making it possible to reduce the waiting time until the temperature is stabilized.

[0041]

[Description of Third Embodiment] Referring next to FIG. 5,

a third embodiment will be described. FIG. 5 shows a partial cross section of a holder table WH improved from that of FIG. 3. The holder table WH in this embodiment is divided into two parts, namely a wafer chuck 90 for holding the wafer W and a ZL stage 82 moving in the Z direction for focus leveling and performing tilt movement, in which wafer chuck 90 is placed on the ZL stage 82. The ZL stage 82 is provided on the XY stage 34 through three z actuators 32A, 32C (32B not shown). Like in FIGS. 1, 3, and 4, the wall LB, the auxiliary plate HRS, the piping 112 for vacuum suction, and passages 53A, 53B communicating with the pipe 53 for supply and discharge of the liquid LQ (see FIG. 4) are formed in the chuck 90, respectively. Note here that the passage 53A communicates with the peripheral part of the auxiliary plate HRS inside the wafer chuck 90, while the passage 53B communicates with the downmost part of the wafer loading portion on the inner bottom of the wafer chuck 90. Thus, since the passages for discharging and filling the liquid are formed at two or more positions, it can be quick to take in or out the liquid.

[0042] Further, in the embodiment, three through-holes (only two of them shown) 91 are formed in the central portion of the chuck 90, and three center-up pins (only two of them shown) 83 moving up and down through the through-holes 91, respectively, are provided on a vertically movement driving mechanism 85. The vertically movement driving mechanism 85 is fixed on the side of the XY stage

34. The three center-up pins 83 are to lift up or down the wafer W on the chuck 90 by a given amount from or onto the loading surface during wafer change. When the wafer W is held on the loading surface of the chuck 90 by vacuum suction as shown in FIG. 5, the tip end of each of the center-up pins 83 is located in a position lower than the loading surface of the chuck 90.

[0043]  On the other hand, a parallel flat plate CG made of quartz silica glass and fixed perpendicularly to the optical axis AX is attached to the tip end of a sub lens-barrel 80 provided in the tip end of the projection lens system PL used in the embodiment so that the front lens element LE1 (plano-convex lens) will not be immersed in the liquid LQ.  In the embodiment, the spacing or distance between the lower face of the parallel flat plate CG and the surface of the wafer W becomes a nominal working distance and is set to 2 mm or less like in the aforementioned embodiments.  The attaching surface of the parallel flat plate CG to the sub lens-barrel 80 is waterproofed and nitrogen gas is filled in the sub lens-barrel 80.

[0044]  Thus, since the parallel flat plate CG is provided at the tip end of the projection lens system PL, even if the substantial backfocus distance (distance from the front optical element having refractive power to the imaging plane) of the projection lens system PL is about 10 to 15 mm, the working distance L can easily be set to about 1 to

2 mm, enabling the implementation of an immersion projection method with reduced influence of temperature changes in the liquid. Further, the parallel flat plate CG can be retrofitted, part of the surface of the parallel flat plate CG can be polished on the order of a fraction of the wavelength, thus making it easy to correct local slight distortion (or random distortion) in the projected image. In other words, the parallel flat plate CG has both a function as a window to protect the front lens element located at the tip end of the projection lens system PL and a function as a distortion correcting plate. From another point of view, it can be said that the image forming performance of the projection lens system PL including the parallel flat plate CG is certified, that is, the parallel flat plate CG remains is consistently a front lens element located at the tip end of the projection lens system PL.

[0045]

[Description of Fourth Embodiment] Referring next to FIG. 6, a fourth embodiment will be described. This embodiment is related to the embodiment shown in FIG. 5 regarding wafer change when the projection optical system having an extremely small working distance is used for an immersion type projection exposure method. In FIG. 6, a reference mirror ML (for X and Y directions) receiving and reflecting a reference beam BSr from the laser interferometer 33 shown in FIG. 1 is fixed in the lower end portion of the lens barrel of the projection lens system PL. In operation, a

length measuring beam BSm from the laser interferometer 33 is projected to a moving mirror MRw fixed to an edge portion of the ZL stage 82 as shown in FIG. 5, and the reflected beam is returned to the laser interferometer 33 so that it will interfere with the reflected beam of the reference beam BSr, thereby measuring the coordinate position of the reflection surface of the moving mirror MRw, that is, the XY coordinate position of the wafer W with reference to the position of the reference mirror ML. In the embodiment, the ZL stage 82 is also mounted on the XY stage 34 through the three Z actuators 32A, 32B (32C not shown) in such a manner that it can move in the Z direction and the tilt direction. Note here that the ZL stage 82 is coupled to the XY stage 34 through leaf springs 84A, 84B (84C not shown) provided at three positions around its perimeter so that it will be supported with extremely high rigidity in the horizontal direction (on the XY plane) with respect to the XY stage 34.

[0046] In the embodiment, the wafer chuck 90 like in FIG. 5 is also provided on the ZL stage 82. A point different from FIG. 5 is that the wafer chuck 90 is configured to move in the Z direction relative to the ZL stage 82 with a relatively large stroke (about 10 to 15 mm) by means of a plurality of Z-direction driving mechanisms 88A, 88B. Unlike the Z actuators 32A, B, C for focus leveling, the driving mechanisms 88A, 88B have only to move the wafer chuck 90 between both ends of the stroke. Therefore, they

can be configured to have a simple elevation function using
an air cylinder or link mechanism. Further, in the
embodiment of FIG. 6, the center-up pins 83 shown in FIG. 5
are fixed on the XY stage 34 without up and down movement.
Then, as shown in FIG. 6, when the wafer chuck 90 is lifted
to its upmost position, the surface of the wafer W is
located 1 to 2 mm from the surface of the front optical
element of the projection lens system PL and the end face
of each of the center-up pins 83 is slightly (about 2 to 3
mm) lower than the wafer loading face of the wafer chuck 90.
[0047] FIG. 6 shows the above-mentioned structure in a
state during exposure of the wafer W. After completion of
the exposure operation, the liquid LQ is temporarily
discharged from the wafer chuck 90 in the manner as shown
in FIG. 4. Then, once the vacuum suction of the wafer chuck
90 is released, the driving mechanisms 88A, 88B are
actuated to lift down the wafer chuck 90 from the position
in FIG. 6 to its downmost position. This causes the wafer W
to be reloaded on the tip end faces of the three center-up
pins 83 while positioning the upper end face of the wall LB
around the wafer chuck 90 to be lower than the front end
surface of the projection lens system PL (the lower face Pe
of the lens element LE1 in FIG. 3 or the lower face of the
parallel flat plate CG in FIG. 5). In this state, if the XY
stage 34 is moved to a wafer change position, the wafer W
is drawn out from the position directly below the
projection lens system PL and moved toward a transport arm

95. At this time, since the arm 95 is set to be higher than the upper end face of the wall LB of the wafer chuck 90 and lower than the wafer W on the center-up pins 83, it gets into the downside of the wafer W. Then, the arm 90 transports the wafer W toward a predetermined unload position while lifting the wafer W slightly up under vacuum suction. The way of carrying in the wafer W is exactly opposite to the above-mentioned sequence.

[0048] As shown in FIG. 6, when the structure is of the type in which the laser interferometer 33 projects the reference beam BSr to the reference mirror ML for the projection lens system PL, since a pool of liquid LQ spreads out intoover the space directly below the optical path of the reference beam BSr, it is considered that a rise of saturated vapor could cause fluctuation in the optical path of the reference beam BSr. Therefore, in the embodiment, a cover plate 87 is arranged between the optical path of the reference beam BSr and the liquid LQ to block the flow of the rising vapor in order to prevent the fluctuation in the optical path of the reference beam BSr.

[0049] In order to more stabilize the optical path of the reference beam BSr, temperature-controlled clean air may be sent in a direction intersecting the optical path over the cover plate 87. In this case, the cover plate 87 also has a function for preventing a direct air blow for air-conditioning of the optical path to the liquid LQ, thus reducing unnecessary evaporation of the liquid LQ.

Alternatively, the entire optical path of the reference beam BSr may be covered with a wind-shielding cylinder instead of such a simple cover plate 87.

[0050]

[Description of Fifth Embodiment] Referring next to FIGS. 7(A) and (B), a fifth embodiment will be described. This embodiment shows a combination of the structure of the holder table WH shown in FIG. 1 with a center-up mechanism (pins 83 and z-driving mechanism 85) shown in FIG. 5, that is, it shows an improved structure of the holder table WH for easy wafer change. FIG. 7(B) is a plan view of the improved holder table WH and FIG. 7(A) is a sectional view taken along the line 7A in FIG. 7(B). It is apparent from FIGS. 7(A),(B) that the holder table WH is held on the XY stage 34 through three Z actuators 32A, 32C (32B not shown), and three through-holes 91 are provided in the central portion of the holder table WH. Center-up pins 83 moving up and down by means of a driving part 85 penetrate through the through-holes 91, respectively.

[0051] As described above, the height of the downmost end face of the projection lens system PL is just about 2 mm from the surface of the auxiliary plate HRS (wafer W) in its original state. In addition, the upper end of the wall LB provided around the holder table WH is higher than the downmost end face of the projection lens system PL. Therefore, if the XY stage 34 is moved for wafer change to draw out the wafer from the position directly below the

projection lens system PL, the width of part of the auxiliary plate HRS will have to be about as large as the diameter of the lens barrel of the projection lens system PL, resulting in an increase in the volume of the holder table WH in which the liquid LQ is filled.

[0052] Therefore, in the embodiment, part of the wall LB of the holder table WH is cut or notched to provide a liquid sealing door DB to freely open or close in the notch portion. The liquid sealing door DB is closed to close the notch portion of the wall LB to seal the liquid while the liquid LQ is being filled as shown in FIGS. 7(A), (B). On the other hand, it is open as indicated by the broken line in FIG. 7(A) while the liquid LQ is being discharged from the holder table WH. The liquid sealing door DB is configured to be slightly higher than the surface of the auxiliary plate HRS when it is in the open state. Further, an O ring OL is provided in position on the wall side (including the notch portion of the wall LB) corresponding to the body side of the holder table WH that encounters the inner wall of the liquid sealing door DB to ensure sealing performance as shown in FIG. 7(B).

[0053] In such a structure, when the wafer on the holder table WH is changed for another, the liquid LQ is first discharged from the holder table WH before opening the liquid sealing door DB. Then, the XY stage 34 is moved to the right in FIG. 7 so that the wafer is drawn out from the position directly below the projection lens system PL. At

this time, the projection lens system PL is located above the liquid sealing door DB that has just been opened. Then, the center-up pins 83 are raised to lift up the wafer to a position higher than the wall LB, thus making it easy to replace the wafer.

[0054] According to the embodiment, the diameter of the wall LB surrounding the perimeter of the holder table WH can be minimized to minimize the total amount of liquid LQ to be filled in the holder table WH. This structure has the advantages of making it easy to manage the temperature of the liquid LQ and minimizing the filling and discharging time of the liquid LQ. In the structure of the fourth embodiment, the liquid sealing door does not need providing because the wafer chuck is lifted down, but such a liquid sealing door may also be provided in the fourth embodiment. [0055]

[Description of Sixth Embodiment] Next, FIG. 8 shows a sixth embodiment of the present invention. In the embodiment, a lower case 7 and an upper case 8 are used. A wafer holder 3a for loading a wafer 3 is formed on the inner bottom of the lower case 7. The upper face of the lower case 7 is hermetically closed by the bottom surface of the upper case 8, and the total volume of the lower case 7 is fully filled with an immersion liquid 7a. The upper case 8 is also filled with an immersion liquid 8a so that the last or front lens surface 1a of a projection optical system 1 will be immersed in an immersion liquid 8a.

[0056]  Part of the immersion liquid 7a in the lower case 7 is guided to a thermoregulator 6 form an outlet 5 provided on one side of the lower case 7 so that the thermoregulator 6 will regulate the temperature of the immersion liquid 7a. The temperature-regulated immersion liquid 7a is then given back to the lower case 7 from an inlet 4 provided on the other side of the lower case 7, thus circulating the immersion liquid 7a.  A plurality of temperature sensors (not shown) are placed at plural positions in the lower case 7 so that the thermoregulator 6 will control the temperature of the immersion liquid 7a in the lower case 7 to be kept constant based on the output of the temperature sensors.  The same temperature control mechanism is also provided for the immersion liquid 8a in the upper case 8.

[0057]  In the embodiment, the lower case 7 and the upper case 8 are integrally moved to move the wafer 3.  On the other hand, since the immersion liquid in the lower case in which the wafer 3 is housed is hemetrically substantially closed, this structure are advantageous not only because of its temperature stability but also because it can prevent the occurrence of a pressure distribution due to an unnecessary flow such as a vortex in the immersion liquid. In other words, a pressure distribution in the immersion liquid causes a fluctuation in refractive index and hence the deterioration of the imaging wavefront aberration. However, in the sixth embodiment, since only the pressure distribution in the immersion liquid 8a filled in the upper

case 8 causes a problem, the optical path in this section $L_8$ can be formed short enough to mitigate the influence of the flow of the immersion liquid during wafer movement to such a level not to cause any practical problem.

[0058] In the embodiment, the lower case 7 and the upper case 8 are integrally moved, but only the lower case 7 can be moved while fixing the upper case 8. In such a structure, the immersion liquid 8a in the upper case 8 completely stops its flow. Therefore, it is preferable that the working distance L be so set that the thickness $L_7$ of the immersion liquid 7a in the lower case 7 will be sufficiently thinner than the thickness $L_8$ of the immersion liquid 8a in the upper case 8.

[0059]

[Description of Alternative Embodiments] Although the embodiments of present invention are described above, since the working distance of the projection lens system during immersion exposure is extremely small, about 1-2 mm, as shown in FIG. 1, the off-axis type focus alignment sensor FAD is used for focusing on the wafer W. Alternatively, a TTL (Through-The-Lens) type focus detection mechanism as disclosed, for example, in US Patent No. 4,801,977 or 4,383,757, may be provided, which projects a focus detection beam onto the wafer through a peripheral part within the projection field of the projection lens system PL to measure the height or tilt of the wafer surface.

[0060] Further, although the focus alignment sensor FAD

shown in FIG. 1 is of an off-axis type that optically detects the alignment marks on the wafer W, this alignment sensor may be of the TTL type that detects the marks on the wafer W through only the projection lens system PL and provided in addition to the TTR alignment sensor 45 in FIG. 1 for detecting the marks on the wafer W through both the reticle R and the projection lens system PL. Furthermore, if the present invention includes a projection optical system for projection exposure under the source of ultraviolet light (having a wavelength of 400 nm or less), it can be applied to any exposure apparatus in the same manner regardless of its structure.

[0061]

[Effects of the Invention] As described above, the present invention provides an immersion exposure apparatus or aligner that can ensure sufficient image forming performance in the range of practically feasible temperature control. The present invention also provides the structure of a wafer stage suitable for loading and unloading a wafer in the immersion alignerexposure apparatus.

[Brief Description of the Drawings]

[FIG. 1] It is a diagram showing the overall structure of a scanning type projection alignerexposure apparatus according to a first embodiment of the present invention.

[FIG. 2] It is a perspective view for schematically explaining a sequence of scanning exposure.

[FIG. 3]  It is a partially sectional view showing a detailed configuration around a projection lens system in FIG. 1.

[FIG. 4]  It is a block diagram schematically showing liquid temperature control and a liquid supply system according to a second embodiment of the present invention.

[FIG. 5]  It is a partially sectional view showing a configuration around a wafer holder and a projection lens system according to a third embodiment of the present invention.

[FIG. 6]  It is a partially sectional view showing a configuration around a wafer holder and a projection lens system according to a fourth embodiment of the present invention.

[FIG. 7]  It includes a sectional view (A) and a plan view (B) showing the structure of a holder table according to a fifth embodiment of the present invention.

[FIG. 8]  It is a schematically sectional view showing the main part of a sixth embodiment of the present invention.

[Description of Notations]

1 … Projection Optical System      1a … Last Lens Surface

7, 8 … Case      7a, 8a … Immersion Liquid

3 … Wafer      3a … Wafer Holder

4 … Inlet      5 … Outlet

6 … Thermoregulator      L … Working Distance

10 … Illumination System      12 …Condenser Lens System

14 … Mirror      16 … Reticle Stage

17 … Laser Interferometer System          18 … Motor

19 … Column Structure          20 … Reticle Stage Controller

30 … Base          32A, 32B, 32C … Actuator

33 … Laser Interferometer System          34 … XY Stage

35 … Wafer Stage Controller          36 … Drive Motor

40 … Main Controller     50A, 50B …Thermoregulator

51 … Groove 51          52 … Passage

53 … Pipe          53A, 53B …Passage

55 … Temperature Sensor          60 … Controller

62 … Selector Valve          64 … Liquid Supply Unit

64A … Pump          64B … Temperature Controller

66 … Drainage Pump 66          80 … Sub Lens-Barrel

82 … ZL Stage          83 … Center-Up Pin

84A, 84B … Leaf Spring  85 … Vertically Driving Mechanism

87 … Cover Plate          88A, 88B … Drive Mechanism

90 … Wafer Chuck          91 … Through-Hole

95 … Arm          112 … Piping

113 … Suction Face          114 … Outer Corner Portion

IL … Pulsed Illumination Light     AI … Illuminated Area

R … Reticle          Pa … Circuit Pattern Area

SB … Light-Shielding Zone     PL … Projection Lens System

AX … Optical Axis          LGa … Front Lens Group System

LGb … Rear Lens Group System          Ep … Projection Pupil

LE1 … Positive Lens Element          Pe … Lower Face

CG … Parallel Flat Plate          W … Wafer

SAa, SAb … Shot Area          SI … Projected Image

WH … Holder Table          LB … Wall

LQ … Liquid          HRS … Auxiliary Plate

DB … Liquid Sealing Door          OL … O Ring

FAD … Focus Alignment Sensor

MRr, MRw … Moving Mirror          ML … Reference Mirror

BSr … Reference Beam          BSm … Measuring Beam

Sf … Focus Signal          Sa … Alignment Signal

| (51)Int.Cl.⁶ | 識別記号 | | FI | | |
|---|---|---|---|---|---|
| HO1L | 21/027 | | HO1L | 21/30 | 515D |
| GO3F | 7/20 | 521 | GO3F | 7/20 | 521 |
| | | | HO1L | 21/30 | 518 |

審査請求　未請求　請求項の数12　FD　（全 14 頁）

(54)【発明の名称】　液浸型露光装置

(57)【要約】
【課題】結像性能の劣化を招くことのない液浸型露光装置を提供する。
【解決手段】レチクルR上に描画されたパターンPaをウエハW上に焼付転写する投影光学系PLを有し、該投影光学系のウエハに最も近接したレンズ面PeとウエハWとの間のワーキングディスタンスのうちの少なくとも一部分を、露光光ILを透過する液体LQで満たした液浸型露光装置において、ワーキングディスタンスの長さをLとし、露光光ILの波長をλとし、液体LQの屈折率の温度係数をN（1／℃）としたとき、L≦λ／（0.3×｜N｜）となるように形成したことを特徴とし、また、液体LQとして、純水の表面張力を減少させ又は純水の界面活性度を増大させる添加剤を純水に添加したものを用いたことを特徴とする。

1
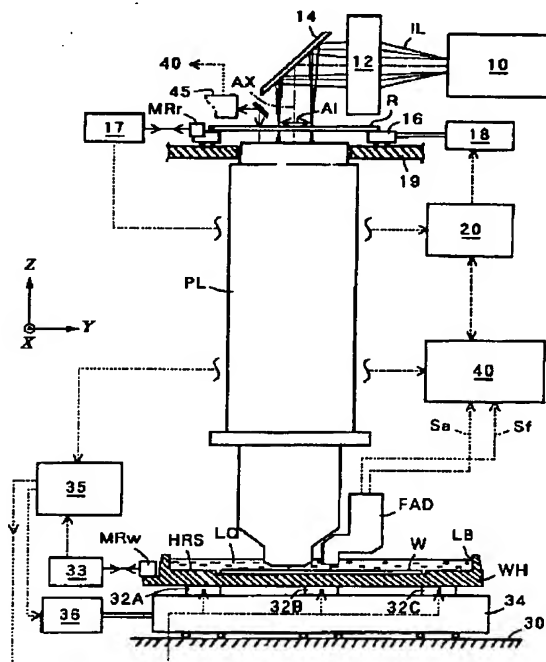
【特許請求の範囲】

【請求項１】レチクル上に描画されたパターンをウエハ上に焼付転写する投影光学系を有し、該投影光学系のウエハに最も近接したレンズ面と前記ウエハとの間のワーキングディスタンスのうちの少なくとも一部分を、露光光を透過する液体で満たした液浸型露光装置において、前記ワーキングディスタンスの長さをＬとし、前記露光光の波長をλとし、前記液体の屈折率の温度係数をＮ（１／℃）としたとき、

Ｌ≦λ／（０．３×｜Ｎ｜）

となるように形成したことを特徴とする液浸型露光装置。

【請求項２】レチクル上に描画されたパターンをウエハ上に焼付転写する投影光学系を有し、該投影光学系のウエハに最も近接したレンズ面と前記ウエハとの間のワーキングディスタンスのうちの少なくとも一部分を、露光光を透過する液体で満たした液浸型露光装置において、前記液体として、純水の表面張力を減少させ又は純水の界面活性度を増大させる添加剤を前記純水に添加したものを用いたことを特徴とする液浸型露光装置。

【請求項３】前記ワーキングディスタンスの長さＬが２ｍｍ以下である、請求項１又は２記載の液浸型露光装置。

【請求項４】前記レチクルとウエハを前記投影光学系の倍率に対応した速度比にて同期して等速に走査可能に配置した、請求項１、２又は３記載の液浸型露光装置。

【請求項５】前記露光光として紫外域の光を用いた、請求項１、２、３又は４記載の液浸型露光装置。

【請求項６】前記投影光学系の最もウエハ側の先端光学素子のウエハ側の光学面を平面状に形成し、前記先端光学素子を保持する鏡筒の下端面を前記光学面と同一平面をなすように形成し、前記鏡筒の下端外周面に面取りを施した、請求項１、２、３、４又は５記載の液浸型露光装置。

【請求項７】前記先端光学素子が平行平板である、請求項６記載の液浸型露光装置。

【請求項８】前記ウエハをホルダテーブルによって保持し、前記液体によってワーキングディスタンスを満たすことができるように前記ホルダテーブルの上面外周に壁部を立設し、前記ホルダテーブル内に前記液体を供給し且つ回収できるように液体供給ユニットを設け、前記ホルダテーブルと液体供給ユニットとの双方に温度調整器を設けた、請求項１～７のいずれか１項記載の液浸型露光装置。

【請求項９】前記ウエハをウエハチャックによって保持し、前記液体によってワーキングディスタンスを満たすことができるように前記ウエハチャックの上面外周に壁部を立設し、前記ウエハチャックを貫通して少なくとも３本のピンを設け、前記ウエハを前記ウエハチャックの上方に持ち上げることができるように、前記ピンに昇降

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駆動装置を取り付けた、請求項１～７のいずれか１項記載の液浸型露光装置。

【請求項１０】前記ウエハをウエハチャックによって保持し、前記液体によってワーキングディスタンスを満たすことができるように前記ウエハチャックの上面外周に壁部を立設し、前記ウエハチャックを貫通して少なくとも３本のピンを設け、ウエハチャックの前記壁部の上端を前記投影光学系の下端よりも低くすることができるように、前記ウエハチャックに昇降駆動装置を取り付けた、請求項１～７のいずれか１項記載の液浸型露光装置。

【請求項１１】前記壁部の一部分に開閉自在な液密ドア部を設けることにより、投影光学系の下端部分との干渉を回避した、請求項１～１０のいずれか１項記載の液浸型露光装置。

【請求項１２】前記投影光学系の側面に干渉計用のミラーを取り付け、該ミラーに入射して反射する光束を前記液体から発する蒸気より離隔するように防護手段を設けた、請求項１～１１のいずれか１項記載の液浸型露光装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、レチクル上に描画されたパターンを投影光学系によってウエハに焼付ける露光装置に関し、特に液浸型の露光装置に関する。

【０００２】

【従来の技術】光学系の最終レンズ面と像面との間の間隔をワーキングディスタンスというが、従来の露光装置の投影光学系のワーキングディスタンスは、空気で満たされていた。このワーキングディスタンスは、オートフォーカス光学系を介在させるなどの都合により、１０ｍ以上取るのが普通であった。他方、ウエハに転写するパターンについては、その微細化がますます望まれており、そのためには露光波長の短波長化を図るか、あるいは開口数の増大を図る必要がある。しかるに短波長の光を透過するガラス材料の種類には限度があるから、ワーキングディスタンスを液体で満たして開口数の増大を図ることにより、露光パターンの微細化を図る液浸型の露光装置が提案されている。

【０００３】液浸型の露光装置では、ワーキングディスタンスに介在させた液体の温度分布によって、屈折率に分布が生じるおそれがある。そこで液体の温度変化に起因する結像性能の劣化への対策として、次のような技術が提案されている。すなわち、（あ）液体の温度安定機構によって温度の安定化を図るものとして、米国特許４，３４６，１６４号の図３に開示された技術が提案されており、加振撹拌機構によって温度の均一化を図るものとして、特開平６－１２４８７３号公報に開示された技術が提案されている。また、（い）液体の温度モニター機構によって温度調節にフィードバックするものとし

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て、同じく特開平6-124873号公報に温度、又は屈折率を計測することが提案されている。

【0004】

【発明が解決しようとする課題】しかし（あ）においては、温度をどの程度安定させれば実用上問題ないかと言った議論は成されておらず、実際には下記に示すように、現実的とは言いがたい精度での温度コントロールが必要になる。また、（い）についても、結像性能に最も影響するのが液体の温度不均一であることを考慮すると、有効な対策とは言い難い。このように液浸型露光装置に関する従来公知の技術においては、ワーキングディスタンスのような投影光学系の光学パラメーターそのものについての制約に言及した例はなく、液浸型の特殊事情が考慮されているとは言えない状況であった。したがって本発明は、ワーキングディスタンスを満たす液体の温度制御を容易にして、結像性能の劣化を招くことのない液浸型露光装置を提供することを課題とする。

【0005】

【課題を解決するための手段】本発明は上記課題を解決するためになされたものであり、すなわち、レチクル上に描画されたパターンをウエハ上に焼付転写する投影光学系を有し、該投影光学系のウエハに最も近接したレンズ面とウエハとの間のワーキングディスタンスのうちの少なくとも一部分を、露光光を透過する液体で満たした液浸型露光装置において、ワーキングディスタンスの長さをLとし、露光光の波長をλとし、液体の屈折率の温度係数をN（1/℃）としたとき、

$$L \leq \lambda / (0.3 \times |N|)$$

【0009】しかるに一般に結像波面収差△Fは、露光波長λの1/30以下が望ましく、すなわち、

$$\Delta F \leq \lambda / 30 \quad \cdots (2)$$

が成立することが好ましい。例えば波長193nmのArFエキシマレーザーを露光光として用いるときには、△F<6.4nmが望ましい。ワーキングディスタンスを満たす媒質が水の場合には、従来技術のようにワーキングディスタンスLがL>10mmでは、媒質の温度分布による結像波面収差の発生量が大きすぎて、実用上問題を生ずることが分かる。

【0010】（1a）式と（2）式とから、

$$L \leq \lambda / (0.3 \times |N|) \quad \cdots (3)$$

を得る。したがって（3）式を満たすことにより、実現可能な温度安定性（温度分布）のもとに、浸液中の温度分布によって生じる波面収差発生量が露光波長の1/30以下に抑えられた投影光学系を搭載した液浸型露光装置が得られる。以上のように本発明においては、温度分布を持った媒質中を露光光が通過することで発生する波

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＊となるように形成したことを特徴とする液浸型露光装置であり、また、前記液体として、純水の表面張力を減少させ又は純水の界面活性度を増大させる添加剤を純水に添加したものを用いたことを特徴とする液浸型露光装置である。

【0006】以下に本発明の作用を説明する。投影光学系の先端のガラス面から結像面までの距離、すなわちワーキングディスタンスをLとし、ワーキングディスタンスLを満たす媒質の温度分布の幅を△Tとし、この温度分布△Tに起因する結像波面の収差を△Fとし、液体の屈折率の温度係数をNとすると、近似的に以下の式（1）が成立する。

$$\Delta F = L \times |N| \times \Delta T \quad \cdots (1)$$

【0007】媒質の温度分布△Tについては、その均一化を図るためにいかにコントロールしようとも、△T=0.01℃程度の温度分布が存在すると想定される。したがって、結像波面収差△Fは、少なくとも、

$$\Delta F = L \times |N| \times 0.01 \quad \cdots (1a)$$

だけは存在する。ここでNは、屈折率の温度係数を1/℃単位で表した値である。

【0008】屈折率の温度係数Nの値は液体と気体で大きく異なり、例えば空気ではN=-9×10⁻⁷/℃であるのに対して、水の場合はN=-8×10⁻⁵/℃であり、100倍近い差がある。他方、縮小投影露光装置の投影光学系のワーキングディスタンスLは、通常L>10mmであるが、L=10mmであるとしても、結像波面収差△Fは以下のようになる。

空気：$\Delta F = 10mm \times |-9 \times 10^{-7}/℃| \times 0.01℃$
$$= 0.09nm$$

水　：$\Delta F = 10mm \times |-8 \times 10^{-5}/℃| \times 0.01℃$
$$= 8.0nm$$

面収差量が、温度分布量と媒質中の光路長の積に依存することに着目し、光路長に上限を設けることにより、温度分布に対する要求を緩和している。これにより実現可能なレベルでの浸液の温度コントロールのもとで、液浸型露光装置を実用に供することができる。

【0011】

【発明の実施の形態】以下に本発明に好適ないくつかの実施例を説明する。

【0012】

【第1の実施例の説明】図1は、本発明の第1の実施例による投影露光装置の全体構成を示し、ここでは、物体側と像側の両側においてテレセントリックに構成された円形イメージフィールドを有する縮小投影レンズ系PLを介して、レチクルR上の回路パターンを半導体ウエハW上に投影しつつ、レチクルRとウエハWとを投影レンズ系PLに対して相対走査するレンズ・スキャン方式の投影露光装置を示す。図1において照明系10は、波長193nmのパルス光を放射するArFエキシマレーザ

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光源（不図示）、その光源からのパルス光の断面形状を整形するビームエクスパンダ（不図示）、その整形されたパルス光を入射して２次光源像（複数の点光源の集まり）を生成するフライ・アイレンズ等のオプチカルインテグレータ（不図示）、その２次光源像からのパルス光を均一な照度分布のパルス照明光にする集光レンズ系（不図示）、そのパルス照明光の形状を走査露光時の走査方向（Ｙ方向）と直交した方向（Ｘ方向）に長い矩形状に整形するレチクルブラインド（照明視野絞り、不図示）、及びそのレチクルブラインドの矩形状の開口からのパルス光ＩＬを図１中のコンデンサーレンズ系１２、ミラー１４と協働してレチクルＲ上にスリット状又は矩形状の照明領域ＡＩとして結像するためのリレー光学系（不図示）とを含んでいる。

【００１３】レチクルＲは、走査露光時には大きなストロークで１次元方向に等速移動可能なレチクルステージ１６上に真空吸着（場合によっては静電吸着、機械締結）される。レチクルステージ１６は、図１においては装置本体のコラム構造体１９上を図中の左右（Ｙ方向）にスキャン移動するようにガイドされ、図の紙面と垂直な方向（Ｘ方向）にも移動するようにガイドされる。そのレチクルステージ１６のＸＹ平面内での座標位置や微小回転量は、レチクルステージ１６の一部に取り付けられた移動鏡（平面鏡やコーナーミラー）ＭＲｒにレーザビームを投射して、その反射ビームを受光するレーザ干渉計システム１７によって逐次計測される。そしてレチクルステージ制御器２０は、干渉計システム１７によって計測されるＸＹ座標位置に基づいてレチクルステージ１６を駆動するためのリニアモータやボイスコイル等のモータ１８を制御し、レチクルステージ１６のスキャン方向の移動と非スキャン方向の移動とを制御する。

【００１４】さて、コンデンサーレンズ系１２とミラー１４から射出された矩形状のパルス照明光ＩＬがレチクルＲ上の回路パターン領域の一部を照射すると、その照明領域ＡＩ内に存在するパターンからの結像光束が１／４倍の縮小投影レンズ系ＰＬを通して、ウエハＷの表面に塗布された感応性のレジスト層に結像投影される。その投影レンズ系ＰＬの光軸ＡＸは、円形イメージフィールドの中心点を通り、照明系１０とコンデンサーレンズ系１２の各光軸とも同軸になるように配置されている。また投影レンズ系ＰＬは、波長１９３ｎｍの紫外線に対して高い透過率を有する石英と螢石の２種類の硝材で作られた複数枚のレンズ素子で構成され、螢石は主に正のパワーを持つレンズ素子に使われる。さらに投影レンズ系ＰＬの複数枚のレンズ素子を固定する鏡筒の内部は、波長１９３ｎｍのパルス照明光の酸素による吸収を避けるために窒素ガスに置換されている。このような窒素ガスによる置換は照明系１０の内部からコンデンサーレンズ系１２（又はミラー１４）までの光路に対しても同様に行われる。

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【００１５】ところで、ウエハＷはその裏面を吸着するホルダテーブルＷＨ上に保持される。このホルダテーブルＷＨの外周部全体には一定の高さで壁部ＬＢが設けられ、この壁部ＬＢの内側には液体ＬＱが所定の深さで満たされている。そしてウエハＷは、ホルダテーブルＷＨの内底部の窪み部分に真空吸着される。またホルダテーブルＷＨの内底部の周辺には、ウエハＷの外周を所定の幅で取り囲むような環状の補助プレート部ＨＲＳが設けられている。この補助プレート部ＨＲＳの表面の高さは、ホルダテーブルＷＨ上に吸着された標準的なウエハＷの表面の高さとほぼ一致するように定められている。

【００１６】この補助プレート部ＨＲＳの主要な機能は、フォーカス・レベリングセンサーの検出点がウエハＷの外形エッジの外側に位置するような場合の代替のフォーカス検出面として利用されることである。また補助プレート部ＨＲＳは、ウエハＷ上のショット領域とレチクルＲ上の回路パターンとを相対的に位置合わせするときに使われるアライメントセンサーのキャリブレーションや、ショット領域を走査露光するときに使われるフォーカス・レベリングセンサーのキャリブレーションにも兼用可能である。ただしアライメントセンサーやフォーカス・レベリングセンサーのキャリブレーションは、補助プレート部ＨＲＳと個別に設けられた専用の基準マーク板を使う方が望ましい。この場合、基準マーク板も液浸状態で投影レンズ系ＰＬの投影像面とほぼ同一の高さになるようにホルダテーブルＷＨ上に取り付けられ、アライメントセンサーは基準マーク板上に形成された各種の基準マークを液浸状態で検出することになる。なお、テーブル上の基準マーク板を使ってフォーカスセンサーのシステム・オフセットをキャリブレーションする方法の一例は、例えば米国特許４，６５０，９８３号に開示され、各種アライメントセンサーのキャリブレーション方法の一例は、例えば米国特許５，２４３，１９５号に開示されている。

【００１７】ところで図１に示した通り、本実施例では投影レンズ系ＰＬの先端部を液体ＬＱ内に浸けるので、少なくともその先端部は防水加工されて鏡筒内に液体が染み込まないような構造となっている。さらに、投影レンズ系ＰＬの先端のレンズ素子の下面（ウエハＷとの対向面）は平面、又は曲率半径が極めて大きい凸面に加工され、これにより、走査露光時にレンズ素子の下面とウエハＷの表面との間で生じる液体ＬＱの流れをスムーズにできる。さらに本実施例では、後で詳細に説明するが、液浸状態における投影レンズ系ＰＬの最良結像面（レチクル共役面）が、先端のレンズ素子の下面から約２～１ｍｍの位置に形成されるように設計されている。従って、先端のレンズ素子の下面とウエハＷの表面との間に形成される液体層の厚みも２～１ｍｍ程度になり、これによって液体ＬＱの温度調整の制御精度が緩和されるとともに、その液体層内の温度分布ムラの発生も抑え

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ることが可能となる。

【0018】さて、ホルダテーブルWHは、投影レンズ系PLの光軸AXに沿ったZ方向への並進移動（本実施例では粗移動と微動）と、光軸AXに垂直なXY平面に対する傾斜微動とが可能なように、XYステージ34上に取り付けられる。このXYステージ34はベース定盤30上をXY方向に2次元移動し、ホルダテーブルWHはXYステージ34上に3つのZ方向用のアクチュエータ32A、32B、32Cを介して取り付けられる。各アクチュエータ32A、B、Cは、ピエゾ伸縮素子、ボイスコイルモータ、DCモータとリフト・カムの組合わせ機構等で構成される。そして3つのZアクチュエータを同じ量だけZ方向に駆動させると、ホルダテーブルWHをZ方向（フォーカス方向）に平行移動させることができ、3つのZアクチュエータを互いに異なる量だけZ方向に駆動させると、ホルダテーブルWHの傾斜（チルト）方向とその量とが調整できる。

【0019】また、XYステージ34の2次元移動は、送りネジを回転させるDCモータや非接触に推力を発生させるリニアモータ等で構成される駆動モータ36によって行われる。この駆動モータ36の制御は、ホルダテーブルWHの端部に固定された移動鏡MRwの反射面のX方向、Y方向の各位置変化を計測するレーザ干渉計33からの計測座標位置を入力するウエハステージ制御器35によって行われる。なお、駆動モータ36をリニアモータとしたXYステージ34の全体構成としては、例えば特開平8−233964号公報に開示された構成を使ってもよい。

【0020】さて、本実施例では投影レンズ系PLのワーキングディスタンスが小さく、投影レンズPLの先端のレンズ素子とウエハWとの間の2〜1mm程度の狭い間隔に液体LQを満たすことから、斜入射光方式のフォーカスセンサーの投光ビームを投影レンズ系PLの投影視野に対応したウエハ面上に斜めに投射することが難しい。このため本実施例では図1に示す通り、オフ・アクシス方式（投影レンズ系PLの投影視野内にフォーカス検出点がない方式）のフォーカス・レベリング検出系と、オフ・アクシス方式でウエハW上のアライメント用のマークを検出するマーク検出系とを含むフォーカス・アライメントセンサーFADを投影レンズ系PLの鏡筒の下端部周辺に配置する。

【0021】このフォーカス・アライメントセンサーFADの先端に取り付けられた光学素子（レンズ、ガラス板、プリズム等）の下面は、図1に示すように液体LQ中に配置され、その光学素子からはアライメント用の照明ビームやフォーカス検出用のビームが液体LQを通してウエハW（又は補助プレート部HRS）の表面上に照射される。そしてフォーカス・レベリング検出系はウエハWの表面の最良結像面に対する位置誤差に対応したフォーカス信号Sfを出力し、マーク検出系はウエハW上

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のマークの光学的な特徴に対応した光電信号を解析して、マークのXY位置又は位置ずれ量を表すアライメント信号Saを出力する。

【0022】そして以上のフォーカス信号Sfとアライメント信号Saは主制御器40に送出され、主制御器40はフォーカス信号Sfに基づいて3つのZアクチュエータ32A、B、Cの各々を最適に駆動するための情報をウエハステージ制御器35に送出する。これによってウエハステージ制御器35は、ウエハW上の実際に投影されるべき領域に対するフォーカス調整やチルト調整が行われるように、各Zアクチュエータ32A、B、Cを制御する。

【0023】また主制御器40は、アライメント信号Saに基づいて、レチクルRとウエハWとの相対的な位置関係を整合させるためのXYステージ34の座標位置を管理する。さらに主制御器40は、ウエハW上の各ショット領域を走査露光する際、レチクルRとウエハWとがY方向に投影レンズ系PLの投影倍率と等しい速度比で等速移動するように、レチクルステージ制御器20とウエハステージ制御器35とを同期制御する。

【0024】なお、図1中のフォーカス・アライメントセンサーFADは投影レンズ系PLの先端部周辺の1ケ所にだけしか設けられていないが、投影レンズ系PLの先端部を挟んでY方向に2ケ所、X方向に2ケ所の計4ケ所に設けておくのがよい。また図1中のレチクルRの上方には、レチクルRの周辺部に形成されたアライメント用のマークとウエハW上のアライメント用のマーク（又は基準マーク板上の基準マーク）とを投影レンズ系PLを通して同時に検出して、レチクルRとウエハWとの位置ずれを高精度に計測するTTR（スルーザレチクル）方式のアライメントセンサー45が設けられている。そしてこのTTRアライメントセンサー45からの位置ずれ計測信号は主制御器40に送出され、レチクルステージ16やXYステージ34の位置決めに使われる。

【0025】ところで図1の露光装置は、XYステージ34をY方向に等速移動させて走査露光を行うものであるが、その走査露光時のレチクルR、ウエハWのスキャン移動とステップ移動とのスケジュールを図2を参照して説明する。図2において、図1中の投影レンズ系PLは、前群レンズ系LGaと後群レンズ系LGbとで代表的に表してあり、その前群レンズ系LGaと後群レンズ系LGbとの間には、投影レンズ系PLの射出瞳Epが存在する。また図2に示したレチクルRには、投影レンズ系PLの物体側の円形イメージフィールドの直径寸法よりも大きな対角長を有する回路パターン領域Paが、遮光帯SBによって区画された内側に形成されている。

【0026】そしてレチクルR上の領域Paは、レチクルRを例えばY軸に沿った負方向に一定速度Vrでスキャン移動させつつ、ウエハWをY軸に沿った正方向に一

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定速度Ｖｗでスキャン移動させることによって、ウエハ
Ｗ上の対応したショット領域ＳＡａに走査露光される。
このとき、レチクルＲを照明するパルス照明光ＩＬの領
域ＡＩは、図２に示すようにレチクル上の領域Ｐａ内で
Ｘ方向に伸びた平行なスリット状又は矩形状に設定さ
れ、そのＸ方向の両端部は遮光帯ＳＢ上に位置する。

【００２７】さて、レチクルＲ上の領域Ｐａ内のパルス
光照明領域ＡＩに含まれる部分パターンは、投影レンズ
系ＰＬ（レンズ系ＬＧａ、ＬＧｂ）によってウエハＷ上
のショット領域ＳＡａ内の対応した位置に像ＳＩとして
結像される。そしてレチクルＲ上のパターン領域Ｐａと
ウエハＷ上のショット領域ＳＡａとの相対走査が完了す
ると、ウエハＷは例えばショット領域ＳＡａの隣りのシ
ョット領域ＳＡｂに対する走査開始位置にくるように、
一定量だけＹ方向にステップ移動される。このステップ
移動の間、パルス照明光ＩＬの照射は中断される。次
に、レチクルＲの領域Ｐａ内のパターンの像がウエハＷ
上のショット領域ＳＡｂに走査露光されるように、レチ
クルＲをパルス光照明領域ＡＩに対してＹ軸の正方向に
一定速度Ｖｒで移動させつつ、ウエハＷを投影像ＳＩに
対してＹ軸の負方向に一定速度Ｖｗで移動させること
で、ショット領域ＳＡｂ上に電子回路のパターン像が形
成される。なお、エキシマレーザ光源からのパルス光を
走査露光に用いる技術の一例は、例えば米国特許４，９
２４，２５７号に開示されている。

【００２８】ところで図１、２に示した投影露光装置
は、レチクルＲ上の回路パターン領域の対角長が投影レ
ンズ系ＰＬの円形イメージフィールドの直径よりも小さ
い場合、照明系１０内のレチクルブラインドの開口の形
状や大きさを変えて、照明領域ＡＩの形状をその回路パ
ターン領域に合わせると、図１の装置をステップ・アン
ド・リピート方式のステッパーとして使うことができ
る。この場合、ウエハＷ上のショット領域を露光してい
る間は、レチクルステージ１６とＸＹステージ３４とを
相対的に静止状態にしておく。しかしながらその露光中
にウエハＷが微動するときは、その微動をレーザ干渉計
システム３３で計測して投影レンズ系ＰＬに対するウエ
ハＷの微小な位置ずれ分をレチクルＲ側で追従補正する
ように、レチクルステージ１６を微動制御すればよい。
またレチクルブラインドの開口の形状や大きさを変える
場合は、開口形状やサイズの変更に合せて、レチクルブ
ラインドに達する光源からのパルス光を調整後の開口に
見合った範囲に集中させるようなズームレンズ系を設け
てもよい。

【００２９】なお、図２から明らかなように、投影像Ｓ
Ｉの領域はＸ方向に延びたスリット状又は矩形状に設定
されているため、走査露光中のチルト調整は本実施例で
は専らＹ軸回りの回転方向、すなわち走査露光の方向に
対してローリング方向にのみ行われる。もちろん、投影
像ＳＩの領域の走査方向の幅が大きく、ウエハ表面の走

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査方向に関するフラットネスの影響を考慮しなければな
らないときは、当然にＸ軸回りの回転方向、すなわちピッ
チング方向のチルト調整も走査露光中に行われる。

【００３０】ここで、本実施例による露光装置の特徴で
あるホルダテーブルＷＨ内の液体ＬＱの状態について、
図３を参照して説明する。図３は投影レンズ系ＰＬの先
端部からホルダテーブルＷＨまでの部分断面を表す。投
影レンズ系ＰＬの鏡筒内の先端には、下面Ｐｅが平面で
上面が凸面の正レンズ素子ＬＥ１が固定されている。こ
のレンズ素子ＬＥ１の下面Ｐｅは、鏡筒金物の先端部の
端面と同一面となるように加工（フラッシュサーフェス
加工）されており、液体ＬＱの流れが乱れることを抑え
ている。さらに投影レンズ系ＰＬの鏡筒先端部で液体Ｌ
Ｑ内に浸かる外周角部１１４は、例えば図３のように大
きな曲率で面取り加工されており、液体ＬＱの流れに対
する抵抗を小さくして不要な渦の発生や乱流を抑える。
また、ホルダテーブルＷＨの内底部の中央には、ウエハ
Ｗの裏面を真空吸着する複数の突出した吸着面１１３が
形成されてい。この吸着面１１３は、具体的には１ｍｍ
程度の高さでウエハＷの径方向に所定のピッチで同心円
状に形成された複数の輪帯状ランド部として作られる。
そして各輪帯状ランド部の中央に刻設された溝の各々
は、テーブルＷＨの内部で真空吸着用の真空源に接続さ
れる配管１１２につながっている。

【００３１】さて、本実施例では図３に示したように、
投影レンズ系ＰＬの先端のレンズ素子ＬＥ１の下面Ｐｅ
とウエハＷ（又は補助プレート部ＨＲＳ）の表面とのベ
ストフォーカス状態での間隔Ｌは、２～１ｍｍ程度に設
定される。そのため、ホルダテーブルＷＨ内に満たされ
る液体ＬＱの深さＨｑは、間隔Ｌに対して２～３倍程度
以上であればよく、従ってホルダテーブルＷＨの周辺に
立設された壁部ＬＢの高さは数ｍｍ～１０ｍｍ程度でよ
い。このように本実施例では、投影レンズ系ＰＬのワー
キングディスタンスとしての間隔Ｌを極めて小さくした
ため、ホルダテーブルＷＨ内に満たされる液体ＬＱの総
量も少なくて済み、温度制御も容易になる。

【００３２】ここで本実施例で使う液体ＬＱは、入手が
容易で取り扱いが簡単な純水を用いる。ただし本実施例
では、液体ＬＱの表面張力を減少させるとともに、界面
活性力を増大させるために、ウエハＷのレジスト層を溶
解させず、且つレンズ素子の下面Ｐｅの光学コートに対
する影響が無視できる脂肪族系の添加剤（液体）をわず
かな割合で添加しておく。その添加剤としては、純水と
ほぼ等しい屈折率を有するメチルアルコール等が好まし
い。このようにすると、純水中のメチルアルコール成分
が蒸発して含有濃度が変化しても、液体ＬＱの全体とし
ての屈折率変化を極めて小さくできるといった利点が得
られる。

【００３３】さて、液体ＬＱの温度はある目標温度に対
して一定の精度で制御されるが、現在比較的容易に温度

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制御できる精度は±０．０１℃程度である。そこでこの
ような温調精度のもとでの現実的な液浸投影法を考えて
みる。一般に空気の屈折率の温度係数$N_a$は約−９×１
$０^{-7}$／℃であり、水の屈折率の温度係数$N_o$は約−８×
$１０^{-5}$／℃であり、水の屈折率の温度係数$N_o$の方が２
桁程度も大きい。一方、ワーキングディスタンスをＬと
すると、ワーキングディスタンスＬを満たす媒質の温度
変化（温度むら）量ΔＴに起因して生じる結像の波面収
差量ΔＦは近似的に次式で表される。

ΔＦ＝Ｌ・｜Ｎ｜・ΔＴ

【００３４】ここで、液浸投影法を適用しない通常の投
影露光の場合、ワーキングディスタンスＬを１０ｍｍ、
温度変化量ΔＴを０．０１℃としたときの波面収差量Δ
$F_{air}$は以下のようになる。

$ΔF_{air}＝Ｌ・｜N_a｜・ΔＴ≒０．０９ｎｍ$

また同じワーキングディスタンスＬと温度変化量ΔＴの
下で、液浸投影法を適用した場合に得られる波面収差量
$ΔF_{10}$は以下のようになる。

$ΔF_{10}＝Ｌ・｜N_o｜・ΔＴ≒８ｎｍ$

【００３５】この波面収差量は、一般に使用波長λの１
／３０ないしは１／５０〜１／１００程度が望ましいと
されているから、ＡｒＦエキシマレーザを使った場合に
許容される最大の波面収差量$ΔF_{max}$は、λ／３０ない
しはλ／５０〜λ／１００程度の６．４３ないしは３．
８６〜１．９３ｎｍに定められ、望ましくはλ／１００
の１．９３ｎｍ以下に定められる。ところで空気と水の
０℃における各熱伝導率は、空気で０．０２４１Ｗ／ｍ
Ｋとなり、水で０．５６１Ｗ／ｍＫとなり、水の方が熱
伝導が良く、水中に形成される光路内での温度むらは空
気中のそれよりも小さくでき、結果的に液体中で発生す
る屈折率の揺らぎも小さくできる。しかしながら、式
（３）に表したようにワーキングディスタンスＬが１０
ｍｍ程度の場合、温度変化量ΔＴが０．０１℃であった
としても、発生する波面収差量$ΔF_{10}$は許容収差量ΔＦ
$_{max}$を大きく越えてしまう。

【００３６】そこで以上の考察から、許容波面収差量Δ
$F_{max}$を考慮した温度変化量ΔＴとワーキングディスタ
ンスＬとの関係は、

$ΔF_{max}＝λ／３０≧Ｌ・｜N_o｜・ΔＴ$

ないしは、

$ΔF_{max}＝λ／１００≧Ｌ・｜N_o｜・ΔＴ$

となる。ここで、想定される温度変化量ΔＴを０．０１
℃、波長λを１９３ｎｍ、そして液体ＬＱの屈折率変化
量$N_o$を−８×$１０^{-5}$／℃とすると、必要とされるワー
キングディスタンス（液体層の厚み）Ｌは、８ｍｍない
しは２．４ｍｍ以下となる。望ましくは、そのワーキン
グディスタンスＬを液体ＬＱがスムーズに流れる範囲内
で２ｍｍよりも小さくした方がよい。以上のように本実
施例のように構成することにより、液体ＬＱの温度制御
が容易になるとともに、液体層内の温度変化に起因した

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波面収差変化で生じる投影像の劣化が抑えられ、極めて
高い解像力でレチクルＲのパターンを投影露光すること
が可能となる。

【００３７】

【第２の実施例の説明】次に、本発明の第２の実施例に
ついて図４を参照して説明する。本実施例は、先の第１
の実施例にも同様に適用可能な液体ＬＱの温度制御法と
ウエハＷの交換時の液体ＬＱの取り扱い方法とを示す。
従って、図４において先の図１，３中の部材と同じもの
には同一の符号をつけてある。さて、図４においてホル
ダテーブルＷＨの内底部に円形の凹部として形成された
ウエハ載置部には複数の吸着面１１３が形成されてい
る。そして円形のウエハ載置部の周辺には、液体ＬＱの
供給と排出に用いる溝５１が環状に形成され、その溝５
１の一部は、テーブルＷＨ内に形成された通路５２を介
して、外部のパイブ５３につながれている。またホルダ
テーブルＷＨ内のウエハ載置部の直下と補助プレート部
ＨＲＳの直下には、ペルチェ素子等の温度調整器５０
Ａ，５０Ｂが埋め込まれ、ホルダテーブルＷＨ上の適当
な位置（望ましくは複数ケ所）には温度センサー５５が
取り付けられて、液体ＬＱの温度が精密に検出される。
そして温度調整器５０Ａ，５０Ｂは、温度センサー５５
によって検出される液体ＬＱの温度が一定値になるよう
に、制御器６０によって制御される。

【００３８】一方、パイブ５３は、切り替えバルブ６２
を介して、液体供給ユニット６４と排出ポンプ６６に接
続されている。切り替えバルブ６２は、制御器６０から
の指令に応答して、液体供給ユニット６４からの液体Ｌ
Ｑをパイブ５３に供給する流路か、パイブ５３からの液
体ＬＱを排出ポンプ６６を介して供給ユニット６４に戻
す流路かを切り替えるように動作する。また供給ユニッ
ト６４内には、ホルダテーブルＷＨ上の液体ＬＱの全体
を収容可能なリザーブタンク（不図示）と、このタンク
から液体ＬＱを供給するポンプ６４Ａと、そのポンプ６
４Ａを含めタンク内の液体ＬＱ全体を一定の温度に保つ
温調器６４Ｂとが設けられている。さらに以上の構成に
おいて、バルブ６２、ポンプ６４Ａ、温調器６４Ｂ、排
出ポンプ６６の各動作は、制御器６０によって統括的に
制御される。

【００３９】さて、このような構成において、ウエハＷ
がホルダテーブルＷＨの載置部上に搬送され、プリアラ
イメントされた状態で複数の吸着面１１３上に載置され
ると、図３に示した真空吸着用の配管１１２を介して減
圧固定される。この間、温度調整器５０Ａ，５０Ｂは、
目標となる温度に制御され続けている。そしてウエハＷ
の真空吸着が完了すると、切り替えバルブ６２がクロー
ズ位置から供給ユニット６４側に切り替わり、温度調整
された液体ＬＱがポンプ６４Ａの作動によって、パイブ
５３、通路５２、溝５１を介してホルダテーブルＷＨの
壁部ＬＢの内部に一定量だけ注入されて、切り替えバル

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ブ６２がクローズ位置に戻る。その後、ウエハＷに対する露光が完了すると、直ちに切り替えバルブ６２がクローズ位置から排出ポンプ６６側に切り替わり、排出ポンプ６６の作動によってテーブルＷＨ上の液体ＬＱが満１、パイプ５３を介して供給ユニット６４のリザーブタンク内に戻される。そのタンク内に戻された液体ＬＱは、リザーブタンク内の温度センサーからの検出信号に基づいて、次のウエハが準備できるまで温調器６４Ｂによって精密に温度制御される。

【００４０】このように本実施例によれば、液浸露光中の液体ＬＱはホルダテーブルＷＨ内の温度調整器５０Ａ，５０Ｂによって温度制御され、ウエハ交換動作中は液体ＬＱを供給ユニット６４内に回収して温度制御するようにしたので、ウエハ交換が大気中で可能になるとともに、液体ＬＱの大きな温度変化を防止できると云った利点がある。さらに本実施例によれば、ウエハ交換後にホルダテーブルＷＨに注入される液体ＬＱは、たとえ設定温度に対して僅か（例えば０．５℃程度）に異なっていたとしても、液体層の深さＨｑ（図３参照）が総じて浅いために比較的早く設定温度に到達し得るから、温度安定を待つ時間も短縮され得る。

【００４１】

【第３の実施例の説明】次に第３の実施例について図５を参照して説明する。図５は先の図３の構成を改良したホルダテーブルＷＨの部分断面を表し、この実施例のホルダテーブルＷＨは、ウエハＷを保持するウエハチャック９０と、フォーカス・レベリングのためのＺ方向移動とチルト移動を行うＺＬステージ８２とに別れており、ＺＬステージ８２上にウエハチャック９０が載置されている。そしてＺＬステージ８２は、３つのＺアクチュエータ３２Ａ，３２Ｃ（３２Ｂは省略）を介して、ＸＹステージ３４上に設けられる。そしてチャック９０には、図１、３、４と同様に、壁部ＬＢ、補助プレート部ＨＲＳ、真空吸着用の配管１１２、液体ＬＱの供給、排出用のパイプ５３（図４参照）に接続される通路５３Ａ，５３Ｂがそれぞれ形成されている。ただし、通路５３Ａはウエハチャック９０内部の補助プレート部ＨＲＳの周辺部分につながっており、通路５３Ｂはウエハチャック９０内底部のウエハ載置部の最も低い部分につながっている。このようにウエハチャック９０内の複数ケ所に液体排出、注入用の通路を形成しておくと、液体の出し入れが迅速に行われる。

【００４２】さらに本実施例では、チャック９０の中央部に３つ（２つのみ図示）の貫通孔９１が形成され、この貫通孔９１を通って上下動する３つ（２つのみ図示）のセンターアップピン８３が、上下動駆動機構８５の上に設けられている。この上下動駆動機構８５は、ＸＹステージ３４側に固定される。その３つのセンターアップピン８３は、ウエハ交換時にチャック９０上のウエハＷを載置面から一定量だけ持ち上げたり、ウエハＷを載置

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面上に下ろしたりするためのものであり、ウエハＷがチャック９０の載置面に真空吸着された状態では、図５に示すようにセンターアップピン８３の先端面は、チャック９０の載置面よりも下がった位置に設定される。

【００４３】一方、本実施例で使用する投影レンズ系ＰＬの先端部には、サブ鏡筒８０の先端に光軸ＡＸと垂直に固定された石英の平行平板ＣＧが取り付けられ、したがって先端のレンズ素子ＬＥ１（平凸レンズ）が液体ＬＱに浸かることがないように構成されている。本実施例では、この平行平板ＣＧの下面とウエハＷの表面との間隔が、見かけ上のワーキングディスタンスとなり、先の実施例と同様に２ｍｍ以下に設定される。またサブ鏡筒８０の平行平板ＣＧとの取付け面は防水加工され、サブ鏡筒８０の内部には窒素ガスが充填されている。

【００４４】このように投影レンズ系ＰＬの先端に平行平板ＣＧを設けるようにすると、投影レンズ系ＰＬの実質的なバックフォーカス距離（屈折力を持つ先端の光学素子から像面までの距離）が１０～１５ｍｍ程度であっても、容易にワーキングディスタンスＬを１～２ｍｍ程度にして液体の温度変化の影響を低減させた液浸投影法が実現できる。また、平行平板ＣＧは後付けで設けることができるから、平行平板ＣＧの表面の一部分を波長の数分の１程度のオーダーで研磨することにより、投影像内で生じている局所的な微少歪曲収差（あるいはランダムなディストーション）を容易に修正することが可能となる。すなわち、平行平板ＣＧは投影レンズ系ＰＬの最先端のレンズ素子を液体から保護する窓としての機能と、ディストーション補正板としての機能とを兼ね備えることになる。なお、別の見方をすれば平行平板ＣＧを含めて投影レンズ系ＰＬの結像性能が保証されているので、平行平板ＣＧが投影レンズ系ＰＬの最先端の光学素子であることに変わりはない。

【００４５】

【第４の実施例の説明】次に本発明の第４の実施例について図６を参照して説明する。本実施例は、先の図５に示した実施例とも関連し、ワーキングディスタンスを極めて小さくした投影光学系を液浸投影露光法に使用した場合のウエハ交換に関するものである。図６において、投影レンズ系ＰＬの鏡筒の下端部には、図１に示したレーザ干渉計３３からの参照用ビームＢＳｒを受けて反射する参照ミラーＭＬ（Ｘ方向用とＹ方向用）が固定されている。そしてレーザ干渉計３３からの測長用ビームＢＳｍは、先の図５に示したようなＺＬステージ８２の端部に固定された移動鏡ＭＲｗに投射され、その反射ビームはレーザ干渉計３３に戻り、参照用ビームＢＳｒの反射ビームと干渉して移動鏡ＭＲｗの反射面の座標位置、すなわちウエハＷのＸ，Ｙ方向の座標位置が、参照ミラーＭＬを基準として計測される。さて、本実施例においても、ＺＬステージ８２は３つのＺアクチュエータ３２Ａ，３２Ｂ（３２Ｃは省略）を介してＸＹステージ３４

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上に取り付けられ、Ｚ方向とチルト方向とに移動可能となっている。ただし、ＺＬステージ８２は、その周辺の３ヶ所で板バネ８４Ａ、８４Ｂ（８４Ｃは省略）を介してＸＹステージ３４と結合され、ＸＹステージ３４に対する水平方向（ＸＹ面内）の剛性が極めて大きくなるように支持される。

【００４６】そして本実施例でも、先の図５と同様のウエハチャック９０がＺＬステージ８２上に設けられるが、図５と異なる点は、ウエハチャック９０を複数のＺ方向の駆動機構８８Ａ、８８Ｂによって比較的に大きなストローク（１０～１５ｍｍ程度）でＺＬステージ８２に対してＺ方向に移動する構成にしたことである。この駆動機構８８Ａ、８８Ｂは、フォーカス・レベリングのためのＺアクチュエータ３２Ａ、Ｂ、Ｃと異なり、ウエハチャック９０をそのストロークの両端間で移動させるだけでよく、エア・シリンダやリンク機構等を使った簡単なエレベーション機能でよい。さらに図６の実施例では、先の図５に示したセンターアップピン８３がＸＹステージ３４上に上下動することなく固定されている。そして図６のようにウエハチャック９０が最も上昇した状態では、ウエハＷの表面が投影レンズ系ＰＬの先端の光学素子の面から１～２ｍｍ程度に設定され、センターアップピン８３の先端面はウエハチャック９０のウエハ載置面よりもわずかに下側（２～３ｍｍ程度）に下がっている。

【００４７】以上のような構成で、図６はウエハＷに対する露光動作時の状態を表し、その露光動作が完了すると先の図４に示した液体ＬＱの排出操作によってウエハチャック９０上の液体ＬＱを一時的に排出する。その後、ウエハチャック９０の真空吸着が解除されると、駆動機構８８Ａ、８８Ｂを作動させてウエハチャック９０を図６の位置から最も下にダウンさせる。これによってウエハＷは３つのセンターアップピン８３の先端面上に載せ替えられるとともに、ウエハチャック９０周辺の壁部ＬＢの上端面が投影レンズ系ＰＬの先端面（図３中ではレンズ素子ＬＥ１の下面Ｐｅ、図５中では平行平板ＣＧの下面）よりも低くなるように位置決めされる。その状態でＸＹステージ３４をウエハ交換位置まで移動させると、ウエハＷは投影レンズ系ＰＬの直下から引き出されて、搬送用のアーム９５の方に移動する。このときアーム９５は、ウエハチャック９０の壁部ＬＢの上端面よりは高く、且つセンターアップピン８３上のウエハＷよりは低くなるような高さに設定された状態で、ウエハＷの下側に入り込む。それからアーム９０はウエハＷを上方向にわずかに持ち上げつつ真空吸着を行い、所定のアンロード位置に向けてウエハＷを搬送する。ウエハＷの搬入は、以上のシーケンスとは全く逆に行われる。

【００４８】ところで図６に示したように、レーザ干渉計３３が参照ビームＢＳｒを投影レンズ系ＰＬの参照ミラーＭＬに投射するような方式の場合、参照ビームＢＳ

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ｒの光路の直下に液体ＬＱのプールが広がっているため、その液体ＬＱの飽和蒸気の上昇によって参照ビームＢＳｒの光路に揺らぎを与えることが考えられる。そこで本実施例では、参照ビームＢＳｒの光路と液体ＬＱとの間にカバー板８７を配置し、液体ＬＱから上昇する蒸気流を遮断して参照ビームＢＳｒの光路で発生する揺らぎを防止する。

【００４９】なお、カバー板８７の上部空間には、参照ビームＢＳｒの光路をより安定にするために、光路と交差する方向に温度制御された清浄な空気を送風してもよい。この場合、カバー板８７は光路空調用の空気が直接液体ＬＱに吹き付けられることを防止する機能も備えることになり、液体ＬＱの不要な蒸発を低減させることができる。また、単なるカバー板８７に代えて、参照ビームＢＳｒの光路全体を遮風筒で覆う構成にしてもよい。

【００５０】

【第５の実施例の説明】次に本発明の第５の実施例を図７（Ａ）、（Ｂ）を参照して説明する。本実施例は先の図１に示したホルダテーブルＷＨの構造に、図５に示したセンターアップ機構（ピン８３、Ｚ駆動部８５）を組合わせたものであり、ウエハ交換を簡単にするようにホルダテーブルＷＨを改良したものである。そして図７（Ｂ）はその改良されたホルダテーブルＷＨの平面を表し、図７（Ａ）は図７（Ｂ）中の７Ａ矢視の断面を表す。その図７（Ａ）、（Ｂ）から分かるように、ホルダテーブルＷＨは、ＸＹステージ３４上に３つのＺアクチュエータ３２Ａ、３２Ｃ（３２Ｂは省略）を介して保持され、ホルダテーブルＷＨの中央付近には３つの貫通孔９１が設けられている。この貫通孔９１には、駆動部８５によって上下動するセンターアップピン８３が通る。

【００５１】先にも説明したように、投影レンズ系ＰＬの最下端面の高さは、そのままでは補助プレート部ＨＲＳ（ウエハＷ）の表面から２ｍｍ程度しか離れていない。さらにホルダテーブルＷＨの周辺に設けられた壁部ＬＢの上端は投影レンズ系ＰＬの最下端面よりも高い。従って、ウエハ交換のためにそのままＸＹステージ３４を移動させて投影レンズ系ＰＬの直下からウエハを引き出すように構成した場合、補助プレート部ＨＲＳの一部分の幅が投影レンズ系ＰＬの鏡筒の直径寸法程度必要となり、液体ＬＱが注入されるホルダテーブルＷＨの内容積を大きくすることになる。

【００５２】そこで本実施例では、図７に示すようにホルダテーブルＷＨの壁部ＬＢの一部を切り欠いて、そこに開閉自在な液密ドア部ＤＢを設けた。この液密ドア部ＤＢは、液体ＬＱが注入されている間は常に図７（Ａ）、（Ｂ）のように壁部ＬＢの切り欠き部を液密状態で閉じており、液体ＬＱがホルダテーブルＷＨ上から排出されると、図７（Ａ）中の破線のように開くようになっている。その液密ドア部ＤＢは、開いた状態では補助プレート部ＨＲＳの表面の高さよりも若干低くなるよ

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うに設定されている。また液密ドア部ＤＢの内壁と接する
ホルダテーブルＷＨ本体側の壁部分（壁部ＬＢの切り
欠き部等）には、図７（Ｂ）のように液密性を確実にす
るＯリングＯＬが適宜の位置に設けられている。

【００５３】以上のような構成において、ホルダテーブ
ルＷＨ上のウエハを交換する場合は、まずホルダテーブ
ルＷＨ内の液体ＬＱを排出してから、液密ドア部ＤＢを
開く。その後、ＸＹステージ３４を図７中で右側に移動
させると、ウエハは投影レンズ系ＰＬの直下から引き出
されることになる。このとき、投影レンズ系ＰＬは丁度
開いた液密ドア部ＤＢの上方空間に位置する。それから
センターアップピン８３を上昇させてウエハを壁部ＬＢ
よりも高く持ち上げれば、ウエハは容易に交換すること
ができる。

【００５４】本実施例によれば、ホルダテーブルＷＨの
周囲を取り囲む壁部ＬＢの直径を最小にすることが可能
となり、ホルダテーブルＷＨ内に満たされる液体ＬＱの
総量を最小限に抑えることが可能となり、液体ＬＱの温
度管理が容易になるだけでなく、液体ＬＱの注入排出時
間も最小になるといった利点がある。なお、前記第４の
実施例の構成のときには、ウエハチャックが下降するか
ら特に液密ドア部を設ける必要はないが、第４の実施例
の構成において、なおも液密ドア部を設けても良い。

【００５５】
【第６の実施例の説明】次に図８は本発明の第６の実施
例を示し、この実施例では下部容器７と上部容器８を用
いている。ウエハ３を載置するウエハホルダー３ａは下
部容器７の内面底部に形成されており、下部容器７の上
面は上部容器８の底面によって密閉されており、下部容
器７の全容積は浸液７ａによって完全に満たされてい
る。他方上部容器８にも浸液８ａが満たされており、そ
の浸液８ａ内に投影光学系１の最終レンズ面１ａが浸さ
れている。

【００５６】下部容器７内の浸液７ａの一部分は、下部
容器７の一側面に設けた排出口５より温度調節器６に導
かれ、温度調節器６において温度調節を受けた後に、下
部容器７の他側面に設けた注入口４より下部容器７に戻
るように循環している。下部容器７内の複数箇所には温
度センサー（図示せず）が取り付けられており、温度調
節器６は温度センサーからの出力に基づいて、下部容器
７内の浸液７ａの温度が一定となるように制御してい
る。また上部容器８内の浸液８ａについても、同様の温
度調節機構が設けられている。

【００５７】この実施例においては、下部容器７と上部
容器８を一体として移動することにより、ウエハ３を移
動している。他方、ウエハ３を収容した下部容器内の浸
液は実質的に密閉されているから、温度安定性の点で有
利であるだけでなく、浸液中の渦等の流れによる圧力分
布も発生しない。すなわち浸液中の圧力分布は、屈折率
の揺らぎとなり結像波面収差悪化の要因となるが、この

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第６の実施例において圧力分布が問題になるのは、上部
容器８に満たされた浸液８ａのみで、この部分の光路Ｌ
ₐを充分に短く形成することにより、ウエハ移動時の浸
液流れの影響を実用上問題にならないレベルまで緩和す
ることが出来る。

【００５８】なお本実施例では下部容器７と上部容器８
を一体として移動したが、下部容器７のみを移動し、上
部容器８を固定することもできる。この構成のときに
は、上部容器８内の浸液８ａは完全に停止することにな
る。したがってワーキングディスタンスＬのうちで、上
部容器８内の浸液８ａの厚さＬₐよりも、下部容器７内
の浸液７ａの厚さＬᵧの方を十分に薄く形成することが
好ましい。

【００５９】
【その他の変形例の説明】以上、本発明の各実施例を説
明したが、先の図１に示したように液浸投影露光時のワ
ーキングディスタンスは１～２ｍｍ程度と極めて小さい
ため、ウエハＷに対する焦点合せはオフ・アクシス方式
のフォーカス・アライメントセンサーＦＡＤを使うもの
とした。しかしながら、例えば米国特許４，８０１，９
７７号、米国特許４，３８３，７５７号等に開示されて
いるように、投影レンズ系ＰＬの投影視野内の周辺部を
介してフォーカス検出用のビームをウエハ上に投射して
ウエハ表面の高さ位置又は傾きを計測するＴＴＬ（スル
ーザレンズ）方式のフォーカス検出機構を設けてもよ
い。

【００６０】また、図１に示したフォーカス・アライメ
ントセンサーＦＡＤは、オフ・アクシス方式でウエハＷ
上のアライメントマークを光学的に検出するものとした
が、このアライメントセンサーもレチクルＲと投影レン
ズ系ＰＬとを通してウエハＷ上のマークを検出する図１
中のＴＴＲアライメントセンサー４５の他に、投影レン
ズ系ＰＬのみを通してウエハＷ上のマークを検出するＴ
ＴＬ方式のアライメントセンサーとしてもよい。さらに
本発明は、紫外線域（波長４００ｎｍ以下）のもとで投
影露光する投影光学系を備えていれば、どのような構成
の露光装置であっても全く同様に適用し得る。

【００６１】
【発明の効果】以上のように本発明により、実現可能な
温度コントロールの範囲内で、充分な結像性能が保証さ
れた液浸型の露光装置が提供された。また、液浸型露光
装置におけるウエハのローディングとアンローディング
に適したウエハステージの構造も提供された。

【図面の簡単な説明】
【図１】本発明の第１の実施例による走査型の投影露光
装置の全体的な構成を示す図である。
【図２】走査露光のシーケンスを模式的に説明するため
の斜視図である。
【図３】図１中の投影レンズ系付近の詳細な構成を示す
部分断面図である。

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【図4】本発明の第2の実施例による液体の温度制御と液体供給システムとを模式的に示すブロック図である。

【図5】本発明の第3の実施例によるウエハホルダーと投影レンズ系付近の構造を示す部分断面図である。

【図6】本発明の第4の実施例によるウエハホルダーと投影レンズ系付近の構造を示す部分断面図である。

【図7】本発明の第5の実施例によるホルダテーブルの構造を示す（A）断面図と、（B）平面図である。
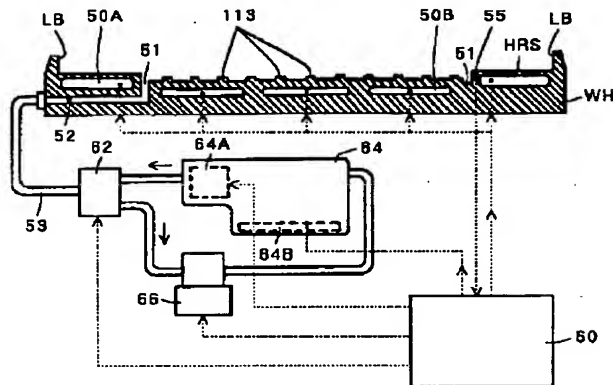
【図8】本発明の第6の実施例の要部を示す概略断面図である。

【符号の説明】

| | |
|---|---|
| 1…投影光学系 | 1a…最終レンズ面 |
| 7、8…容器 | 7a、8a…浸液 |
| 3…ウエハ | 3a…ウエハホルダー |
| 4…注入口 | 5…排出口 |
| 6…温度調節器 | L…ワーキングディスタンス |
| 10…照明系レンズ系 | 12…コンデンサー |
| 14…ミラー | 16…レチクルステージ |
| 17…レーザ干渉計システム | 18…モータ |
| 19…コラム構造体 | 20…レチクルステージ制御器 |
| 30…ベース定盤 | 32A、32B、32C…アクチュエータ |
| 33…レーザ干渉計システム | 34…XYステージ |
| 35…ウエハステージ制御器 | 36…駆動モータ |
| 40…主制御器 | 50A、50B…温度調整器 |
| 51…溝51 | 52…通路 |
| 53…パイプ路 | 53A、53B…通路 |

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| | |
|---|---|
| ＊55…温度センサー | 60…制御器 |
| 62…切り替えバルブユニット | 64…液体供給ユニット |
| 64A…ポンプ | 64B…温調器 |
| 66…排出ポンプ66 | 80…サブ鏡筒 |
| 82…ZLステージ | 83…センターアップピン |
| 84A、84B…板バネ | 85…上下動駆動機構 |
| 87…カバー板 | 88A、88B…駆動機構 |
| 90…ウエハチャック | 91…貫通孔 |
| 95…アーム | 112…配管 |
| 113…吸着面 | 114…外周角部 |
| IL…パルス照明光 | AI…照明領域 |
| R…レチクル領域 | Pa…回路パターン |
| SB…遮光帯 | PL…投影レンズ系 |
| AX…光軸系 | LGa…前群レンズ |
| LGb…後群レンズ系 | Ep…射出瞳 |
| LE1…正レンズ素子 | Pe…下面 |
| CG…平行平板 | W…ウエハ |
| SAa、SAb…ショット領域 | SI…投影像 |
| WH…ホルダテーブル | LB…壁部 |
| LQ…液体ト部 | HRS…補助プレート |
| DB…液密ドア部 | OL…Oリング |
| FAD…フォーカス・アライメントセンサー | |
| MRr、MRw…移動鏡 | ML…参照ミラー |
| BSr…参照用ビーム | BSm…測長用ビーム |
| Sf…フォーカス信号 | Sa…アライメント信号 |

【図4】



【図8】

【図1】

【図2】



【図3】

【図５】



【図６】
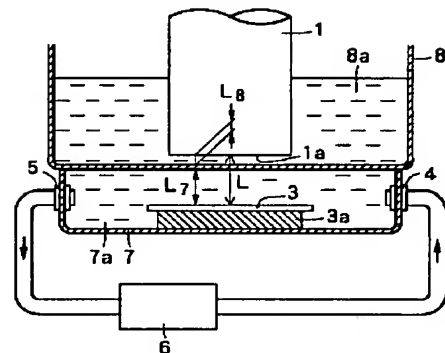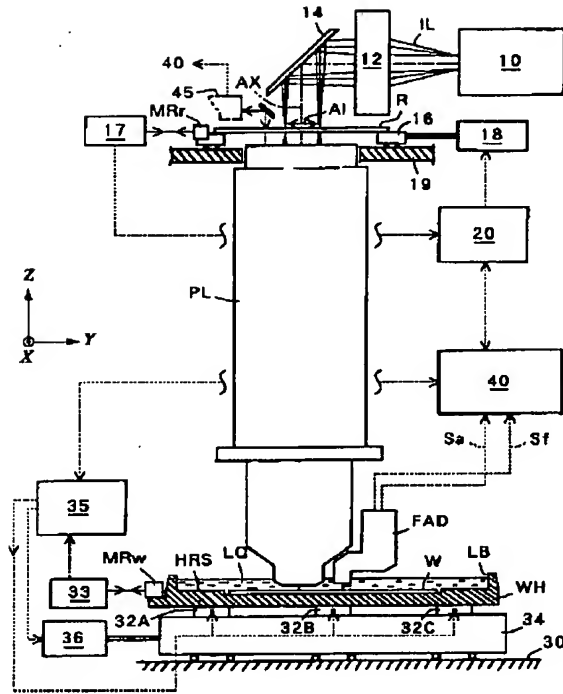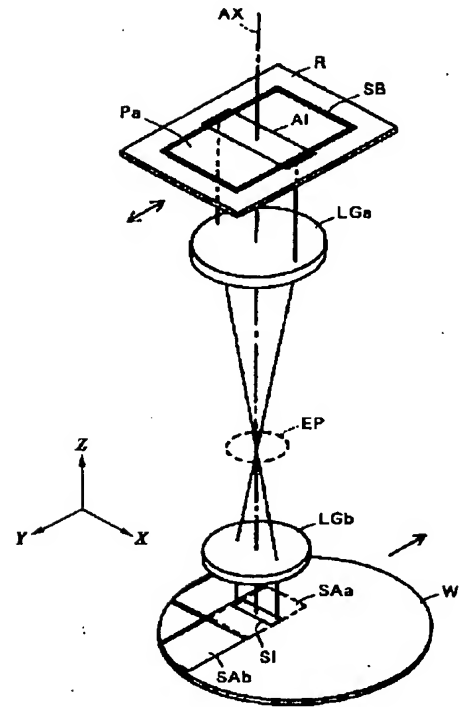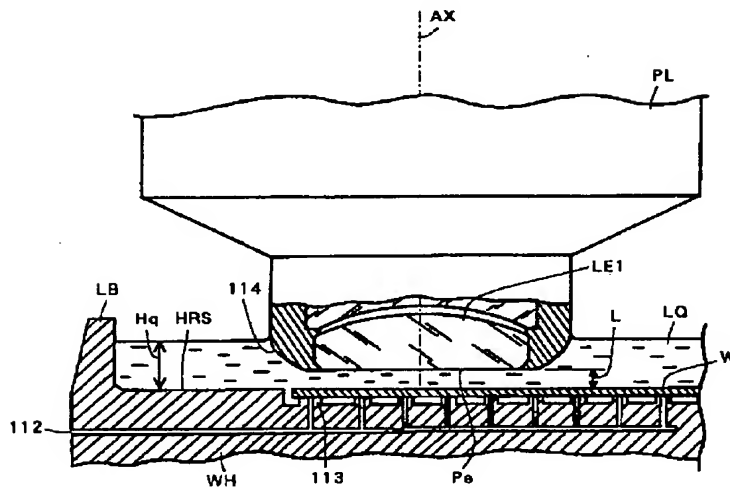
【図7】

(A)
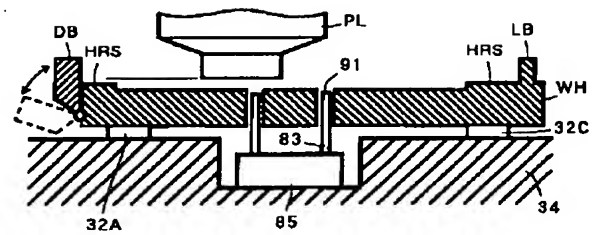


(B)

[JP,10-303114,A]

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CLAIMS

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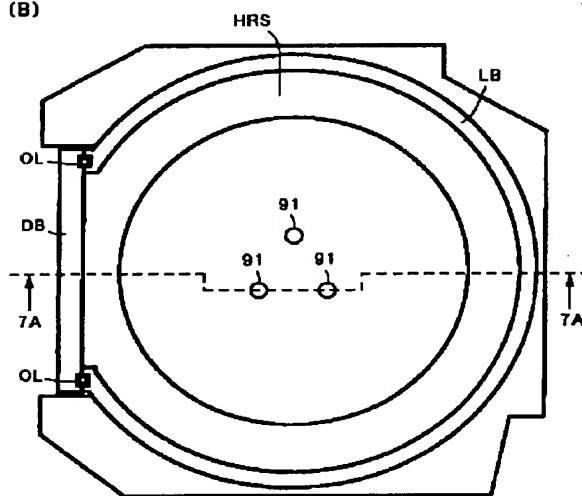[Claim(s)]
[Claim 1] It has the projection optical system which carries out the printing imprint of the pattern drawn on reticle on a wafer. In the immersion photolithography system which filled at least the part of the working distances between the lens side which approached the wafer of this projection optical system most, and said wafer with the liquid which penetrates exposure light When the die length of said working distance is set to L, wavelength of said exposure light is set to lambda and the temperature coefficient of the refractive index of said liquid is set to N (1-/degree C), it is L<=lambda/(0.3x|N|).
The immersion photolithography system characterized by forming so that it may become.
[Claim 2] It has the projection optical system which carries out the printing imprint of the pattern drawn on reticle on a wafer. In the immersion photolithography system which filled at least the part of the working distances between the lens side which approached the wafer of this projection optical system most, and said wafer with the liquid which penetrates exposure light The immersion photolithography system characterized by using what added the additive which decreases the surface tension of pure water or increases whenever [ surface activity / of pure water ] as said liquid to said pure water.
[Claim 3] The immersion photolithography system according to claim 1 or 2 whose die-length L of said working distance is 2mm or less.
[Claim 4] The immersion photolithography system according to claim 1, 2, or 3 which synchronized with the velocity ratio corresponding to the scale factor of said projection optical system, and has arranged said reticle and wafer possible [ a scan ] to uniform velocity.
[Claim 5] The immersion photolithography system according to claim 1, 2, 3, or 4 using the light of an ultraviolet area as said exposure light.
[Claim 6] The immersion photolithography system according to claim 1, 2, 3, 4, or 5 which formed the soffit side of the lens-barrel which forms the optical surface by the side of the wafer of the head optical element by the side of a wafer in a plane most, and holds said head optical element of said projection optical system so that the same flat surface as said optical surface might be made, and beveled to the soffit peripheral face of said lens-barrel.
[Claim 7] The immersion photolithography system according to claim 6 said whose head optical element is a parallel plate.
[Claim 8] The immersion photolithography system of claim 1-7 given in any 1 term which held said wafer on the holder table, set up the wall on the top-face periphery of said holder table so that working distance could be filled with said liquid, prepared the liquid supply unit so that said liquids could be supplied and collected in said holder table, and prepared the both sides of said holder table and a liquid supply unit the heat regulator.

[Claim 9] The immersion photolithography system of claim 1-7 given in any 1 term which attached the rise-and-fall driving gear in said pin so that said wafer is held by the wafer chuck, a wall is set up on the top-face periphery of said wafer chuck so that working distance can be filled with said liquid, said wafer chuck might be penetrated, at least three pins might be prepared and said wafer could be lifted above said wafer chuck.

[Claim 10] The immersion photolithography system of claim 1-7 given in any 1 term which attached the rise-and-fall driving gear in said wafer chuck so that said wafer is held by the wafer chuck, a wall is set up on the top-face periphery of said wafer chuck so that working distance can be filled with said liquid, said wafer chuck might be penetrated, at least three pins might be prepared and the upper bed of said wall of a wafer chuck could be made lower than the soffit of said projection optical system.

[Claim 11] The immersion photolithography system of claim 1-10 given in any 1 term which avoided interference with the soffit part of a projection optical system by preparing the fluid-tight door section which can be freely opened and closed to said a part of wall.

[Claim 12] The immersion photolithography system of claim 1-11 given in any 1 term which established the protection means so that it might be isolated from the steam which emits the flux of light which carries out incidence of the mirror for interferometers to installation and this mirror, and is reflected in the side face of said projection optical system from said liquid.

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DETAILED DESCRIPTION

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[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates especially to the aligner of an immersion type about the aligner which bakes the pattern drawn on reticle on a wafer according to a projection optical system.

[0002]

[Description of the Prior Art] Although spacing between the last lens side of optical system and the image surface was called working distance, the working distance of the projection optical system of the conventional aligner was filled with air. As for this working distance, it was common to have taken 10mm or more on account of making autofocus optical system intervene etc. On the other hand, the detailed-ization is desired increasingly and it is necessary to attain short wavelength-ization of exposure wavelength for that purpose, or to aim at buildup of numerical aperture about the pattern imprinted to a wafer. However, since there is a limit in the class of glass ingredient which penetrates the light of short wavelength, the aligner of the immersion type which attains detailed-ization of an exposure pattern is proposed by filling working distance with a liquid and aiming at buildup of numerical aperture.

[0003] In the aligner of an immersion type, there is a possibility that distribution may arise in a refractive index according to the temperature distribution of the liquid made to be placed between working distances. Then, the following techniques are proposed as a cure to degradation of the image formation engine performance resulting from the

temperature change of a liquid. That is, the technique indicated by drawing 3 of a U.S. Pat. No. 4,346,164 number is proposed according to the temperature stability device of a liquid (**) as what attains stabilization of temperature, and the technique indicated by JP,6-124873,A is proposed as what attains equalization of temperature by the excitation agitator style. Moreover, measuring temperature or a refractive index to JP,6-124873,A similarly as what is fed back to temperature control according to the temperature monitor device of a liquid (being) is proposed.

[0004]

[Problem(s) to be Solved by the Invention] However (**), if it sets and how many temperature is stabilized, as shown below actually, the temperature control in the precision which is hard to be referred to as realistic is needed [ the argument referred to as whether it is satisfactory practically is not accomplished, but ]. moreover -- (-- it is --) -- ******** -- if it takes into consideration that the temperature ununiformity of a liquid influences the image formation engine performance most, it will be hard to call it an effective cure. Thus, it was in the situation which cannot be conventionally referred to as that there is no example which mentioned the constraint about the optical parameter of a projection optical system like working distance itself in the well-known technique about an immersion photolithography system, and the special conditions of an immersion type are taken into consideration. Therefore, this invention makes easy temperature control of the liquid which fills working distance, and makes it a technical problem to offer the immersion photolithography system which does not cause degradation of the image formation engine performance.

[0005]

[Means for Solving the Problem] It is made in order that this invention may solve the above-mentioned technical problem. It has the projection optical system which carries out the printing imprint of the pattern drawn on reticle on a wafer. In the immersion photolithography system which filled at least the part of the working distances between the lens sides and wafers which approached the wafer of this projection optical system most with the liquid which penetrates exposure light When the die length of working distance is set to L, wavelength of exposure light is set to lambda and the temperature coefficient of the refractive index of a liquid is set to N (1-/degree C), it is L<=lambda/(0.3x|N|).

It is the immersion photolithography system characterized by forming so that it may become, and it is the immersion photolithography system characterized by using what added the additive which decreases the surface tension of pure water or increases whenever [ surface activity / of pure water ] as said liquid to pure water.

[0006] An operation of this invention is explained below. If set the distance from the glass side at the head of a projection optical system to an image formation side, i.e., working distance, to L, width of face of the temperature distribution of the medium which fills working distance L is set to deltaT, aberration of the image formation wave front resulting from this temperature-distribution deltaT is set to deltaF and the temperature coefficient of the refractive index of a liquid is set to N, the following formulas (1) will be materialized in approximation.

deltaF=Lx|N|xdeltaT .... (1)

[0007] About temperature-distribution deltaT of a medium, in order to attain the

equalization, it controls how and a way is assumed that about [ deltaT=0.01 degree C ] temperature distribution exist. Therefore, image formation wave aberration deltaF is deltaF=Lx|N|x0.01 at least. .... (1a)

**** exists. N is the value which expressed the temperature coefficient of a refractive index with the 1/degree-C unit here.

[0008] The values of the temperature coefficient N of a refractive index differ greatly with a liquid and a gas, for example, with air, to being N=-9x10-7/degree C, in the case of water, it is N=-8x10-5/degree C, and it has an about 100 times as many difference as this. On the other hand, although the working distance L of the projection optical system of a cutback projection aligner is usually L> 10mm, though it is L= 10mm, image formation wave aberration deltaF of the working distance is as follows.

Air: deltaF=10mmx|-9x10-7/degree-C|x0.01 degree C = 0.09nm Water : deltaF=10mmx|-8x10-5/degree-C|x0.01 degree C = 8.0nm [0009] However, generally, 1/30 or less [ of the exposure wavelength lambda ] is desirable, namely, image formation wave aberration deltaF is delta F<=lambda / 30. .... (2)

******(ing) is desirable. For example, deltaF<6.4nm is desirable when using an ArF excimer laser with a wavelength of 193nm as an exposure light. When the medium which fills working distance is water, by L> 10mm, it turns out like the conventional technique that the yield of the image formation wave aberration according [ working distance L ] to the temperature distribution of a medium is too large, and a problem is produced practically.

[0010] (1a) From a formula and (2) types to L<=lambda/(0.3x|N|) .... (3)

******. Therefore, by filling (3) types, the immersion photolithography system which carried the projection optical system by which the wave aberration yield produced according to the temperature distribution in an immersion liquid on the basis of realizable temperature stability (temperature distribution) was stopped by 1/30 or less [ of exposure wavelength ] is obtained. The amount of wave aberration generated because exposure light passes through the inside of the medium which had temperature distribution in this invention is easing the demand to temperature distribution by preparing the optical path length an upper limit as mentioned above paying attention to being dependent on the product of the optical path length in the amount of temperature distributions, and a medium. Practical use can be presented with an immersion photolithography system under the temperature control of the immersion liquid in level realizable by this.

[0011]

[Embodiment of the Invention] Some suitable examples for this invention are explained below.

[0012]

[Explanation of the 1st example] Drawing 1 shows the whole projection aligner configuration by the 1st example of this invention, and it shows the projection aligner of the lens scanning method which carries out the relative scan of Reticle R and the wafer W to projection lens system PL here, projecting the circuit pattern on Reticle R on the semi-conductor wafer W through cutback projection lens-system PL which has the circular image field constituted by the tele cent rucksack in the both sides by the side of a body and an image. The ArF excimer laser to which an illumination system 10

emits pulsed light with a wavelength of 193nm in drawing 1 (un-illustrating), The beam expander which operates the cross-section configuration of the pulsed light from the light source orthopedically (un-illustrating), Optical integrators, such as a fly eye lens which carries out incidence of the pulsed light operated orthopedically, and generates secondary light source images (meeting of two or more point light sources) (un-illustrating), The condenser lens system which makes pulsed light from the secondary light source image the pulse illumination light of uniform illuminance distribution (un-illustrating), the reticle blind (a lighting field diaphragm ··) which operates the configuration of the pulse illumination light orthopedically in the shape of [ long ] a rectangle in the direction (the direction of X) which intersected perpendicularly with the scanning direction at the time of scan exposure (the direction of Y) The relay optical system (un-illustrating) for collaborating with the condenser-lens system 12 in drawing 1 and a mirror 14, and carrying out image formation of the pulsed light IL from opening of the shape of un-illustrating and a rectangle of the reticle blind on Reticle R as a lighting field A.I. Artificial Intelligence of the shape of the shape of a slit and a rectangle is included.

[0013] At the time of scan exposure, vacuum adsorption (depending on the case, they are electrostatic adsorption and machine conclusion) of the reticle R is carried out in the direction of one dimension on the movable uniform reticle stage 16 by big stroke. In drawing 1 , a reticle stage 16 is guided so that scanning migration of the column structure 19 top of the body of equipment may be carried out at the right and left in drawing (the direction of Y), and it is guided so that it may move also in the direction (the direction of X) vertical to the space of drawing. The coordinate location and minute rotation in XY flat surface of the reticle stage 16 project a laser beam on the migration mirror (a plane mirror and corner mirror) MRr attached in a part of reticle stage 16, and are serially measured by the laser interferometer system 17 which receives the reflective beam. And the reticle stage controller 20 controls the motors 18, such as a linear motor for driving a reticle stage 16 based on XY coordinate location measured by interferometer systems 17, and a voice coil, and controls migration of the scanning direction of a reticle stage 16, and migration of the non-scanning direction.

[0014] Now, if the rectangle-like pulse illumination light IL injected from the condenser-lens system 12 and the mirror 14 irradiates a part of circuit pattern space on Reticle R, the image formation flux of light from the pattern which exists in the lighting field A.I. Artificial Intelligence will let 1/4 time as many cutback projection lens system PL as this pass, and image formation projection will be carried out at the sensitive resist layer applied to the front face of Wafer W. The optical axis AX of the projection lens system PL passes along the central point of the circular image field, and it is arranged so that it may become the same axle also to each optical axis of an illumination system 10 and the condenser-lens system 12. Moreover, projection lens system PL consists of lens elements of two or more sheets made from two kinds of ** material, a quartz and a fluorite, which has high permeability to ultraviolet rays with a wavelength of 193nm, and a fluorite is used for the lens element which mainly has forward power. The interior of the lens-barrel which furthermore fixes the lens element of two or more sheets of projection lens system PL is permuted by nitrogen gas, in order to avoid absorption by the oxygen of the pulse illumination light with a

wavelength of 193nm. The permutation by such nitrogen gas is similarly performed to the optical path from the interior of an illumination system 10 to the condenser-lens system 12 (or mirror 14).

[0015] By the way, Wafer W is held on the holder table WH which adsorbs the rear face. Wall LB is formed in the whole periphery section of this holder table WH in fixed height, and Liquid LQ is filled with the predetermined depth inside this wall LB. And vacuum adsorption of the wafer W is carried out at the hollow part of the inner pars basilaris ossis occipitalis of the holder table WH. Moreover, the annular auxiliary plate section HRS which encloses the periphery of Wafer W by predetermined width of face is formed around the inner pars basilaris ossis occipitalis of the holder table WH. It is determined that the height of the front face of this auxiliary plate section HRS is mostly in agreement with the height of the front face of the standard wafer W which adsorbed on the holder table WH.

[0016] The main functions of this auxiliary plate section HRS are used as a focal detection side of an alternative of a case so that the detecting point of a focal leveling sensor may be located in the outside of the appearance edge of Wafer W. Moreover, the auxiliary plate section HRS can be used also [ calibration / the calibration of the alignment sensor used when carrying out alignment of the shot field on Wafer W, and the circuit pattern on Reticle R relatively, and / of the focal leveling sensor used when carrying out scan exposure of the shot field ]. However, it is more desirable to use for the calibration of an alignment sensor or a focal leveling sensor the reference mark plate of the dedication established according to the auxiliary plate section HRS and an individual. In this case, it will be attached on the holder table WH so that a reference mark plate may also become the almost same height as the projection image side of projection lens system PL in the state of immersion, and an alignment sensor will detect various kinds of reference marks formed on the reference mark plate in the state of immersion. In addition, an example of the approach of carrying out the calibration of the system offset of a focal sensor using the reference mark plate on a table is indicated by for example, the U.S. Pat. No. 4,650,983 number, and an example of the calibration approach of various alignment sensors is indicated by for example, the U.S. Pat. No. 5,243,195 number.

[0017] By the way, since the point of projection lens system PL is soaked in Liquid LQ in this example as shown in drawing 1 , the point at least has the structure where it is waterproofed and a liquid does not sink in in a lens-barrel. Furthermore, the underside (opposed face with Wafer W) of the lens element at the head of projection lens system PL is processed into a flat surface or a convex with very large radius of curvature, and, thereby, can make smooth flow of the liquid LQ produced between the underside of a lens element, and the front face of Wafer W at the time of scan exposure. Furthermore, by this example, although explained to a detail later, the best image formation side (reticle conjugation side) of projection lens system PL in an immersion condition is designed so that it may be formed in the location of about 2-1mm from the underside of the lens element at a head. Therefore, while the thickness of the liquid layer formed between the underside of the lens element at a head and the front face of Wafer W is also set to about 2-1mm and the control precision of the temperature control of Liquid LQ is eased by this, it becomes possible to also suppress generating of the

temperature-distribution nonuniformity in the liquid layer.

[0018] Now, the holder table WH is attached on X-Y stage 34 so that the advancing-side-by-side migration (it moves slightly with rough migration in this example) to the Z direction in alignment with the optical axis AX of projection lens system PL and dip jogging to XY flat surface vertical to an optical axis AX may be possible. This X-Y stage 34 carries out two-dimensional migration of the base surface plate 30 top in the XY direction, and the holder table WH is attached through three actuators 32A, 32B, and 32C for Z directions on X-Y stage 34. Each actuator 32A, and B and C consist of combination devices of a piezo flexible component, a voice coil motor, a DC motor, and a lift cam etc. And if only the same amount makes a Z direction drive three Z actuators, parallel translation of the holder table WH can be carried out to a Z direction (the direction of a focus), and if only a mutually different amount makes a Z direction drive three Z actuators, the dip (tilt) direction and amount of the holder table WH can be adjusted.

[0019] Moreover, two-dimensional migration of X-Y stage 34 is performed by the drive motor 36 which consists of linear motors which make the DC motor made to rotate a delivery screw and non-contact generate a thrust. Control of this drive motor 36 is performed by the wafer stage controller 35 which inputs the measurement coordinate location from the laser interferometer 33 which measures each location change of the direction of X of the reflector of the migration mirror MRw fixed to the edge of the holder table WH, and the direction of Y. In addition, as a whole X-Y stage 34 configuration which used the drive motor 36 as the linear motor, the configuration indicated by JP,8-233964,A, for example may be used.

[0020] Now, in this example, since the working distance of projection lens system PL is small and Liquid LQ is filled in narrow spacing of about 2-1mm between the lens element at the head of the projection lens PL, and Wafer W, it is difficult to project aslant on the wafer side corresponding to the projection visual field of projection lens system PL the floodlighting beam of the focal sensor of an oblique incidence light method. For this reason, in this example, the focal alignment sensor FAD containing the focal leveling detection system of an off-axis method (method which does not have a point detecting [ focal ] into the projection visual field of projection lens system PL), and the mark detection system which detects the mark for the alignment on Wafer W by the off-axis method is arranged on the outskirts of the soffit section of the lens-barrel of projection lens system PL as shown in drawing 1 .

[0021] The underside of the optical elements (a lens, a glass plate, prism, etc.) attached at the head of this focal alignment sensor FAD is arranged in Liquid LQ, as shown in drawing 1 , and from that optical element, the lighting beam for alignment and the beam for focal detection are irradiated on the front face of Wafer W (or auxiliary plate section HRS) through Liquid LQ. And a focal leveling detection system outputs the focal signal Sf corresponding to the position error over the best image formation side of the front face of Wafer W, and a mark detection system analyzes the photoelectrical signal corresponding to the optical description of the mark on Wafer W, and outputs the alignment signal Sa showing XY location or the amount of location gaps of a mark.

[0022] And the above focal signal Sf and alignment signal Sa are sent out to a master controller 40, and a master controller 40 sends out the information for driving three

each of Z actuator 32A, and B and C the optimal based on the focal signal Sf to the wafer stage controller 35. The wafer stage controller 35 controls Z actuator each 32A, and B and C by this so that the focal adjustment and tilt adjustment to the field which should be projected actually on Wafer W are performed.

[0023] Moreover, a master controller 40 manages the coordinate location of X-Y stage 34 for adjusting the relative physical relationship of Reticle R and Wafer W based on the alignment signal Sa. Furthermore, in case a master controller 40 carries out scan exposure of each shot field on Wafer W, as Reticle R and Wafer W carry out uniform migration with an equal velocity ratio with the projection scale factor of projection lens system PL in the direction of Y, it carries out the synchronousr control of the reticle stage controller 20 and the wafer stage controller 35.

[0024] In addition, the focal alignment sensor FAD in drawing 1 is good to prepare in the direction of Y at two places, and to prepare in the direction of X on both sides of the point of projection lens system PL, at two places [ a total of four ], although only one place of the point circumference of projection lens system PL is prepared. Moreover, the mark for alignment formed in the periphery of Reticle R and the mark for the alignment on Wafer W (or reference mark on a reference mark plate) are simultaneously detected above the reticle R in drawing 1 through projection lens system PL, and the alignment sensor 45 of the TTR (SURUZA reticle) method which measures the location gap with Reticle R and Wafer W to high degree of accuracy is formed in it. And the location gap measurement signal from this TTR alignment sensor 45 is sent out to a master controller 40, and is used for positioning of a reticle stage 16 or X-Y stage 34.

[0025] By the way, although the aligner of drawing 1 makes the uniform migration of X-Y stage 34 carry out in the direction of Y and performs scan exposure, it explains the reticle R at the time of the scan exposure, and the schedule of scanning migration of Wafer W and step migration with reference to drawing 2 . In drawing 2 , projection lens system PL in drawing 1 is typically expressed with the pre-group lens system LGa and the rear group lens system LGb, and the exit pupil Ep of projection lens system PL exists between the pre-group lens system LGa and rear group lens system LGb. Moreover, circuit pattern space Pa which has bigger diagonal length than the diameter dimension of the circular image field by the side of the body of projection lens system PL in the reticle R shown in drawing 2 is formed in the inside divided with the protection-from-light band SB.

[0026] And scan exposure of the field Pa on Reticle R is carried out in Reticle R to the shot field SAa to which it corresponded on Wafer W by making the scanning migration of the wafer W carry out in the forward direction in alignment with a Y-axis with constant speed Vw, making scanning migration carry out in the negative direction in alignment with a Y-axis with constant speed Vr. At this time, the field A.I. Artificial Intelligence of the pulse illumination light IL which illuminates Reticle R is set up the shape of the parallel shape of a slit, and a rectangle extended in the direction of X in the field Pa on reticle, as shown in drawing 2 , and the both ends of that direction of X are located on the protection-from-light band SB.

[0027] Now, image formation of the partial pattern contained in the pulse Mitsuteru light region A.I. Artificial Intelligence in the field Pa on Reticle R is carried out to the

location where it corresponded in the shot field SAa on Wafer W by projection lens system PL (lens systems LGa and LGb) as an image SI. And completion of a relative scan with pattern space Pa on Reticle R and the shot field SAa on Wafer W carries out step migration only of the constant rate in the direction of Y so that Wafer W may come to the scan starting position to the shot field SAb of the next door of the shot field SAa. The exposure of the pulse illumination light IL is interrupted during this step migration. Next, the pattern image of an electronic circuitry is formed on the shot field SAb by moving Wafer W in the negative direction of a Y-axis with constant speed Vw to a projection image SI, moving Reticle R in the forward direction of a Y-axis with constant speed Vr to the pulse Mitsuteru light region A.I. Artificial Intelligence so that scan exposure of the image of the pattern in the field Pa of Reticle R may be carried out to the shot field SAb on Wafer W. In addition, a technical example which uses the pulsed light from an excimer laser for scan exposure is indicated by for example, the U.S. Pat. No. 4,924,257 number.

[0028] By the way, if drawing 1 and the projection aligner shown in 2 change the configuration and magnitude of opening of a reticle blind within an illumination system 10 and the configuration of the lighting field A.I. Artificial Intelligence is doubled with the circuit pattern space when the diagonal length of the circuit pattern space on Reticle R is smaller than the diameter of the circular image field of projection lens system PL, the equipment of drawing 1 can be used for it as a stepper of a step-and-repeat method. In this case, while exposing the shot field on Wafer W, the reticle stage 16 and X-Y stage 34 are relatively made into the quiescent state. However, what is necessary is just to carry out jogging control of the reticle stage 16 so that the jogging may be measured by the laser interferometer system 33 and flattery amendment of the part for the location gap with minute Wafer W to projection lens system PL may be carried out by Reticle R side when Wafer W moves slightly during the exposure. Moreover, when changing the configuration and magnitude of opening of a reticle blind, a zoom lens system which is centralized on the range corresponding to opening after adjusting the pulsed light from the light source which reaches a reticle blind to compensate for modification of an opening configuration or size may be prepared.

[0029] In addition, to the hand of cut of scan exposure of the circumference of a Y-axis, i.e., the direction, since the field of a projection image SI is set up the shape of the shape of a slit, and a rectangle prolonged in the direction of X so that clearly from drawing 2 , tilt adjustment under scan exposure is chiefly performed only in the rolling direction by this example. Of course, the width of face of the scanning direction of the field of a projection image SI is large, and if it is ******, when there is nothing in consideration of the effect of the flatness about the scanning direction on the front face of a wafer, naturally tilt adjustment of the hand of cut of the circumference of the X-axis, i.e., the pitching direction, is also performed during scan exposure.

[0030] Here, the condition of the liquid LQ in the holder table WH which is the description of the aligner by this example is explained with reference to drawing 3 . Drawing 3 expresses the partial cross section from the point of projection lens system PL to the holder table WH. The convex positive lens component LE 1 is being fixed [ Underside Pe ] at the head in the lens-barrel of projection lens system PL for the top

face at the flat surface. The underside Pe of this lens element LE1 is processed so that it may become the end face of the point of lens-barrel hardware, and the same field (flash plate surface processing), and it is suppressing that the flow of Liquid LQ is confused. Beveling processing is carried out with big curvature like drawing 3 , and the periphery corner 114 furthermore soaked in Liquid LQ by the lens-barrel point of projection lens system PL makes resistance to the flow of Liquid LQ small, and suppresses generating and the turbulent flow of an unnecessary eddy. Moreover, the adsorption side 113 where the plurality which carries out vacuum adsorption of the rear face of Wafer W projected is formed in the center of the inner pars basilaris ossis occipitalis of the holder table WH, and it is **. This adsorption side 113 is specifically made from height of about 1mm as two or more zona-orbicularis-like lands formed in the direction of a path of Wafer W in the predetermined pitch concentric circular. And each of the slot engraved in the center of each zona-orbicularis-like land has led to the piping 112 connected to the source of a vacuum for vacuum adsorption inside Table WH.

[0031] Now, in this example, as shown in drawing 3 , the spacing L in the best focus condition of the underside Pe of lens element LE1 at the head of projection lens system PL and the front face of Wafer W (or auxiliary plate section HRS) is set as about 2-1mm. Therefore, the height of the wall LB set up to spacing L around the holder table WH that what is necessary is [ therefore ] just about 2 to 3 or more times of the depth Hq of the liquid LQ filled in the holder table WH is good at several mm - about 10mm. Thus, the spacing L as working distance of projection lens system PL is written very small, and there are also few total amounts of the liquid LQ filled in the holder table WH, it ends with this example, and temperature control also becomes easy.

[0032] The liquid LQ used by this example here is easy to receive, and handling uses easy pure water. However, at this example, while decreasing the surface tension of Liquid LQ, in order to increase the surface activity force, the additive (liquid) of the aliphatic series system which is not made to dissolve the resist layer of Wafer W, and can disregard the effect to the optical coat of the underside Pe of a lens element is added at few rate. The methyl alcohol which has a refractive index almost equal to pure water as the additive is desirable. If it does in this way, even if the methyl alcohol component in pure water evaporates and content concentration changes, the advantage that refractive-index change as the whole liquid LQ can be made very small will be acquired.

[0033] Now, although the temperature of Liquid LQ is controlled by fixed precision to a certain target temperature, a current comparison precision which can carry out temperature control easily is about **0.01 degrees C. Then, the realistic immersion projection under such a temperature control precision is considered. general -- the temperature coefficient Na of the refractive index of air -- about -9x10-7/degree C -- it is -- the temperature coefficient Nq of the refractive index of water -- about -- it is -8x10-5/degree C, and the temperature coefficient Nq of the refractive index of water is larger about double figures. On the other hand, when working distance is set to L, amount of wave aberration deltaF of the image formation which originates in amount [ of temperature changes (temperature unevenness) ] deltaT of the medium which fills working distance L, and is produced is expressed with a degree type in approximation.

deltaF=Land | N | -deltaT [0034] Here, in the usual projection exposure which does not apply immersion projection, amount of wave aberration deltaFair when making 10mm and amount of temperature changes deltaT into 0.01 degrees C is as follows about working distance L.

deltaFair=Land | Na | -delta -- amount of wave aberration deltaFlq obtained under the working distance L with $T**0.09nm$ same again and amount of temperature changes deltaT when immersion projection is applied is as follows.

deltaFlq=L, | Nq |, and deltaT**8nm[0035] The greatest amount of wave aberration deltaFmax by which this amount of wave aberration is generally permitted 1/30 of the operating wavelength lambda or 1 / when ArF excimer laser is used since 50 to about 1/100 is made desirable is set to lambda/30, lambda / about 50 to lambda/100 6.43, or 3.86-1.93nm, and is desirably set to lambda/100 of 1.93nm or less. By the way, each thermal conductivity in 0 degree C of air and water serves as 0.0241 W/mK with air, and it becomes 0.561 W/mK with water, and water of heat conduction is better, it can do smaller than it in air, and the temperature unevenness within the optical path formed underwater can also make small fluctuation of the refractive index generated in a liquid as a result. However, as expressed to the formula (3), when working distance L is about 10mm, even if amount of temperature changes deltaT is 0.01 degrees C, amount of wave aberration deltaFlq to generate will exceed amount of permissible aberration deltaFmax greatly.

[0036] Then, the relation of the amount of temperature changes deltaT and working distance L in consideration of amount of allowance wave aberration deltaFmax is set to deltaFmax=lambda/30>=L- | Nq | -deltaT, or delta Fmax=lambda / 100 >=L, | Nq | and deltaT from the above consideration. Here, if amount of temperature changes deltaT assumed is made into 0.01 degrees C and 193nm and refractive-index variation Nq of Liquid LQ are made into -8x10-5/degree C for wavelength lambda, the working distance (thickness of a liquid layer) L needed will be set to 8mm or 2.4mm or less. It is better to make the working distance L smaller than 2mm desirably within limits to which Liquid LQ flows smoothly. While the temperature control of Liquid LQ becomes easy by constituting like this example as mentioned above, degradation of the projection image produced in the wave aberration change resulting from the temperature change in a liquid layer is suppressed, and it becomes possible to carry out projection exposure of the pattern of Reticle R by very high resolving power.

[0037]

[Explanation of the 2nd example] Next, the 2nd example of this invention is explained with reference to drawing 4 . This example shows the temperature control method of the applicable liquid LQ, and operating of the liquid LQ at the time of exchange of Wafer W also like the 1st previous example. Therefore, the same sign is attached to previous drawing 1 and the same thing as the member in three in drawing 4 . Now, two or more adsorption sides 113 are formed in the wafer installation section formed in the inner pars basilaris ossis occipitalis of the holder table WH as a circular crevice in drawing 4 . And the slot 51 used for supply and blowdown of Liquid LQ is formed around the circular wafer installation section annularly, and a part of the slot 51 is connected with the external pipe ·53 through the path 52 formed in Table WH. Moreover, the heat regulators 50A and 50B, such as a Peltier device, are embedded

directly under [ of the wafer installation section in the holder table WH ], and directly under the auxiliary plate section HRS, a thermo sensor 55 is attached in the suitable location on the holder table WH (desirably two or more places), and the temperature of Liquid LQ is detected by the precision. And heat regulators 50A and 50B are controlled by the controller 60 so that the temperature of the liquid LQ detected by the thermo sensor 55 becomes constant value.

[0038] On the other hand, the pipe 53 is connected to the liquid supply unit 64 and the drainage pump 66 through the change bulb 62. The change bulb 62 answers a command from a controller 60, and it operates so that the passage which supplies the liquid LQ from the liquid supply unit 64 to a pipe 53, and the passage which returns the liquid LQ from a pipe 53 to the supply unit 64 through a drainage pump 66 may be changed. Moreover, in the supply unit 64, thermoregulator 64B which maintains at fixed temperature whole liquid LQ in a tank including pump 64A which supplies Liquid LQ, and its pump 64A from the reserve tank (un-illustrating) which can hold the whole liquid LQ on the holder table WH, and this tank is prepared. Furthermore in the above configuration, each actuation of a bulb 62, pump 64A, thermoregulator 64B, and a drainage pump 66 is controlled by the controller 60 in generalization.

[0039] Now, in such a configuration, if Wafer W is laid on two or more adsorption sides 113 in the condition, PURIARAIMENTO [ conveyed and ] on the installation section of the holder table WH, reduced pressure immobilization will be carried out through the piping 112 for vacuum adsorption shown in drawing 3 . In the meantime, it is being continued by controlling heat regulators 50A and 50B the temperature used as a target. And if vacuum adsorption of Wafer W is completed, the change bulb 62 will change from a closing location to the supply unit 64 side, the liquid LQ by which the temperature control was carried out will be poured in only for a constant rate inside the wall LB of the holder table WH through a pipe 53, a path 52, and a slot 51 by actuation of pump 64A, and the change bulb 62 will return to a closing location. Then, shortly after the exposure to Wafer W is completed, the change bulb 62 changes from a closing location to a drainage-pump 66 side, and is returned in the reserve tank of the supply unit 64 through the liquid LQ fang furrow 51 on Table WH, and a pipe 53 by actuation of a drainage pump 66. Based on the detecting signal from the thermo sensor in a reserve tank, temperature control of it is carried out to a precision by thermoregulator 64B until the liquid LQ returned in the tank can prepare the following wafer.

[0040] Thus, since according to this example temperature control of the liquid LQ under immersion exposure was carried out, Liquids LQ are collected in the supply unit 64 and it was made to carry out temperature control during wafer exchange actuation with the heat regulators 50A and 50B in the holder table WH, while wafer exchange is attained in atmospheric air, there is an advantage referred to as being able to prevent the big temperature change of Liquid LQ. the liquid LQ which is furthermore poured into the holder table WH after wafer exchange according to this example -- even if -- laying temperature -- receiving -- being small (for example, about 0.5 degrees C) -- though it differs, since the depth Hq (refer to drawing 3 ) of a liquid layer is shallow generally and laying temperature may be reached comparatively early, the time amount which waits for temperature stability may also be shortened.

[0041]
[Explanation of the 3rd example] Next, the 3rd example is explained with reference to drawing 5 . Drawing 5 expresses the partial cross section of the holder table WH which improved the configuration of previous drawing 3 , the holder table WH of this example has separated on the wafer chuck 90 holding Wafer W, and the ZL stage 82 which performs the Z direction migration and tilt migration for focal leveling, and the wafer chuck 90 is laid on the ZL stage 82. And the ZL stage 82 is formed on X-Y stage 34 through three Z actuators 32A and 32C (32B omits). And the paths 53A and 53B connected to Wall LB, the auxiliary plate section HRS, the piping 112 for vacuum adsorption, supply of Liquid LQ, and the pipe 53 (refer to drawing 4 ) for blowdown are formed in the chuck 90 like drawing 1 , and 3 and 4, respectively. However, path 53A is connected with the circumference part of the auxiliary plate section HRS of the wafer chuck 90 interior, and path 53B is connected with the lowest part of the wafer installation section of the pars basilaris ossis occipitalis in the wafer chuck 90. Thus, formation of the path for liquid blowdown and the impregnation in the wafer chuck 90 to two or more places performs receipts and payments of a liquid promptly.
[0042] Furthermore, by this example, three breakthroughs (two are illustrated) 91 are formed in the center section of a chuck 90, and three pin center,large rise pins (two are illustrated) 83 which move up and down through this breakthrough 91 are formed on the vertical-movement drive 85. Besides, the downward moving drive 85 is fixed to an X-Y stage 34 side. The three pin center,large rise pins 83 are for only a constant rate lifting the wafer W on a chuck 90 from an installation side at the time of wafer exchange, or taking down Wafer W on an installation side, and where vacuum adsorption of the wafer W is carried out in the installation side of a chuck 90, as shown in drawing 5 , the apical surface of the pin center,large rise pin 83 is set as the location which fell rather than the installation side of a chuck 90.
[0043] On the other hand, it is constituted by the point of projection lens system PL used by this example so that the parallel plate CG of the quartz fixed at right angles to an optical axis AX may be attached at the head of the sub lens-barrel 80, therefore lens element LE1 (plano-convex lens) at a head may not be soaked in Liquid LQ. In this example, spacing of the underside of this parallel plate CG and the front face of Wafer W serves as working distance on appearance, and is set as 2mm or less like a previous example. Moreover, the anchoring side with the parallel plate CG of the sub lens-barrel 80 is waterproofed, and the interior of the sub lens-barrel 80 is filled up with nitrogen gas.
[0044] Thus, if the parallel plate CG is formed at the head of projection lens system PL, even if a substantial back focus distance (distance from the optical element at a head with refractive power to the image surface) of projection lens system PL is about 10-15mm, the immersion projection which working distance L was easily set [ projection ] to about 1-2mm, and reduced the effect of the temperature change of a liquid is realizable. Moreover, since the parallel plate CG can be formed by post-installation, it becomes possible [ correcting easily the local very small distortion aberration (or random distortion) produced within the projection image ] by grinding a part of front face of the parallel plate CG to the 1/several about order of wavelength. That is, the parallel plate CG will combine the function as an aperture which protects

the latest lens element of projection lens system PL from a liquid, and the function as a distortion compensation plate. In addition, since the image formation engine performance of projection lens system PL including the parallel plate CG is guaranteed if another view is carried out, a change does not have the parallel plate CG in it being the latest optical element of projection lens system PL.
[0045]
[Explanation of the 4th example] Next, the 4th example of this invention is explained with reference to drawing 6 . This example is connected also with the example shown in previous drawing 5 , and is related with the wafer exchange at the time of using the projection optical system which made working distance very small for the immersion projection exposing method. In drawing 6 , the reference mirror ML (the object for the directions of X and for the directions of Y) reflected in response to the beam BSr for reference from the laser interferometer 33 shown in drawing 1 is being fixed to the soffit section of the lens-barrel of projection lens system PL. And the beam BSm for length measurement from a laser interferometer 33 is projected by the migration mirror MRw fixed to the edge of the ZL stage 82 as shown in previous drawing 5 , the reflective beam interferes in a laser interferometer 33 with the reflective beam of return and the beam BSr for reference, and the coordinate location of the reflector of the migration mirror MRw, i.e., X of Wafer W, and the coordinate location of the direction of Y are measured on the basis of the reference mirror ML. Now, also in this example, the ZL stage 82 is attached on X-Y stage 34 through three Z actuators 32A and 32B (32C omits), and is movable in a Z direction and the direction of a tilt. However, it is combined with X-Y stage 34 through flat springs 84A and 84B (84C omits) by three places of the circumference of it, and the ZL stage 82 is supported so that the rigidity of the horizontal direction (inside of XY side) to X-Y stage 34 may become very large.
[0046] And although the wafer chuck 90 as previous drawing 5 also with the same this example is formed on the ZL stage 82, a different point from drawing 5 is having made it the configuration which boils the wafer chuck 90 comparatively with the drives 88A and 88B of two or more Z directions, and moves to a Z direction to the ZL stage 82 by big stroke (about 10-15mm). unlike Z actuator 32A for focal leveling, and B and C, these drives 88A and 88B move the wafer chuck 90 among the ends of that stroke -- sufficient -- it is good at the easy elevation function using an air cylinder, a link mechanism, etc. Furthermore in the example of drawing 6 , it is fixed, without the pin center,large rise pin 83 shown in previous drawing 5 moving up and down on X-Y stage 34. And after the wafer chuck 90 has gone up most like drawing 6 , the front face of Wafer W was set as about 1-2mm from the field of the optical element at the head of projection lens system PL, and the apical surface of the pin center,large rise pin 83 has fallen to the down side (about 2-3mm) more slightly than the wafer installation side of the wafer chuck 90.
[0047] With the above configurations, drawing 6 will discharge the liquid LQ on the wafer chuck 90 temporarily by blowdown actuation of the liquid LQ shown in previous drawing 4 , if the condition at the time of the exposure actuation to Wafer W is expressed and the exposure actuation is completed. Then, if vacuum adsorption of the wafer chuck 90 is canceled, Drives 88A and 88B will be operated and the wafer chuck

90 will be brought down at the bottom from the location of drawing 6 . While Wafer W is again carried by this on three apical surfaces of the pin center,large rise pin 83, it is positioned so that the upper bed side of the wall LB of the wafer chuck 90 circumference may become lower than the apical surface (the inside of drawing 3 the inside of the underside Pe of lens element LE1, and drawing 5 underside of the parallel plate CG) of projection lens system PL. If X-Y stage 34 is moved to a wafer exchange location in the condition, Wafer W will be pulled out from directly under [ of projection lens system PL ], and will move to the direction of the arm 95 for conveyance. It is in the condition set as height which becomes lower than the wafer W on the pin center,large rise pin 83 more highly than the upper bed side of the wall LB of the wafer chuck 90 at this time as for an arm 95, and enters into Wafer W bottom. And an arm 90 performs vacuum adsorption, lifting Wafer W slightly upward, and conveys Wafer W towards a predetermined unload location. Carrying in of Wafer W is completely carried out to reverse with the above sequence.

[0048] By the way, since the pool of Liquid LQ spreads out directly under the optical path of a reference beam BSr in the case of a method with which a laser interferometer 33 projects a reference beam BSr on the reference mirror ML of projection lens system PL as shown in drawing 6 , it is possible to give fluctuation to the optical path of a reference beam BSr by lifting of the saturated steam of the liquid LQ. So, in this example, the covering plate 87 is arranged between the optical path of a reference beam BSr, and Liquid LQ, and the fluctuation which intercepts the steamy style which goes up from Liquid LQ, and is generated in the optical path of a reference beam BSr is prevented.

[0049] In addition, the up space of the covering plate 87 may be ventilated in the pure air by which temperature control was carried out in the direction which intersects an optical path, in order to make the optical path of a reference beam BSr stability more. In this case, the covering plate 87 will be equipped also with the function to prevent that the air for optical-path air conditioning is sprayed on the direct liquid LQ, and can reduce unnecessary evaporation of Liquid LQ. Moreover, it may replace with the mere covering plate 87, and the whole optical path of a reference beam BSr may be made a wrap configuration with a windshield tube.

[0050]

[Explanation of the 5th example] Next, the 5th example of this invention is explained with reference to drawing 7 R> 7 (A) and (B). This example combines the pin center,large rise device (a pin 83, Z actuator 85) shown in drawing 5 with the structure of the holder table WH shown in previous drawing 1 , and it improves the holder table WH so that wafer exchange may be simplified. And drawing 7 (B) expresses the flat surface of the improved holder table WH, and drawing 7 (A) expresses the cross section of 7A view in drawing 7 (B). The holder table WH is held through three Z actuators 32A and 32C (32B omits) on X-Y stage 34, and three breakthroughs 91 are formed near the center of the holder table WH so that the drawing 7 (A) and (B) may show. In this breakthrough 91, the pin center,large rise pin 83 which moves up and down by the actuator 85 passes.

[0051] As explained also in advance, if the height of the lowest end face of projection lens system PL remains as it is, it is separated from the front face of the auxiliary plate

section HRS (wafer W) only about 2mm. The upper bed of the wall LB furthermore prepared around the holder table WH is higher than the lowest end face of projection lens system PL. Therefore, when it constitutes so that X-Y stage 34 may be moved as it is for wafer exchange and a wafer may be pulled out from directly under [ of projection lens system PL ], a part of width of face of the auxiliary plate section HRS will enlarge content volume of the holder table WH on which the diameter dimension extent required next door of the lens-barrel of projection lens system PL and Liquid LQ are poured in.

[0052] So, in this example, as shown in drawing 7 , a part of wall LB of the holder table WH was cut and lacked, and the fluid-tight door section DB which can be opened and closed freely there was formed. While Liquid LQ is poured in, this fluid-tight door section DB has always closed the notching section of Wall LB in the state of fluid-tight, as shown in drawing 7 (A) and (B), and if Liquid LQ is discharged from the holder table WH, it will open it like the broken line in drawing 7 (A). In the condition of having opened, the fluid-tight door section DB is set up so that it may become low a little rather than the height of the front face of the auxiliary plate section HRS. Moreover, O ring OLs (notching section of Wall LB etc.) who ensure fluid-tight nature like drawing 7 (B) are prepared in the proper location at a part for the wall by the side of the holder table WH body which touches the wall of the fluid-tight door section DB.

[0053] In the above configurations, when exchanging the wafer on the holder table WH, after discharging the liquid LQ in the holder table WH first, the fluid-tight door section DB is opened. Then, when X-Y stage 34 is moved to right-hand side in drawing 7 , a wafer will be pulled out from directly under [ of projection lens system PL ]. Projection lens system PL is located in the headroom of the fluid-tight door section DB opened exactly at this time. And a wafer is easily exchangeable, if the pin center,large rise pin 83 is raised and a wafer is lifted more highly than Wall LB.

[0054] There is an advantage temperature management of Liquid LQ not only becomes easy, but that become possible to make into min the diameter of the wall LB which encloses the perimeter of the holder table WH according to this example, become possible to stop the total amount of the liquid LQ filled in the holder table WH to the minimum, and the impregnation blowdown time amount of Liquid LQ becomes min. In addition, although it is not necessary at the time of the configuration of said 4th example to prepare the fluid-tight door section especially since a wafer chuck descends, in the configuration of the 4th example, the fluid-tight door section may be prepared still more.

[0055]
[Explanation of the 6th example] Next, drawing 8 shows the 6th example of this invention, and uses the lower container 7 and the up container 8 in this example. Wafer electrode-holder 3a which lays a wafer 3 is formed in the inner surface pars basilaris ossis occipitalis of the lower container 7, the top face of the lower container 7 is sealed by the base of the up container 8, and the complete product of the lower container 7 is thoroughly filled by immersion liquid 7a. Immersion liquid 8a is filled by the another side up container 8, and last lens side 1a of a projection optical system 1 is dipped in the immersion liquid 8a.

[0056] A part of immersion liquid 7a in the lower container 7 is led to a

thermoregulator 6 from the exhaust port 5 prepared in one side face of the lower container 7, and in a thermoregulator 6, it circulates through temperature control so that it may return to the lower part [ inlet / 4 / which was established in the other side faces of the lower container 7 after the carrier beam ] container 7. The thermo sensor (not shown) is attached in two or more [ in the lower container 7 ], and based on the output from a thermo sensor, the thermoregulator 6 is controlled so that the temperature of immersion liquid 7a in the lower container 7 becomes fixed. Moreover, the same temperature regulatory mechanism is prepared also about immersion liquid 8a in the up container 8.

[0057] In this example, the wafer 3 is moved by moving the lower container 7 and the up container 8 as one. On the other hand, since the immersion liquid in the lower container which held the wafer 3 is sealed substantially, it is not only advantageous in respect of temperature stability, but it does not generate the pressure distribution by flow, such as an eddy in an immersion liquid. that is , although the pressure distribution in an immersion liquid serve as fluctuation of a refractive index and it become the factor of image formation wave aberration aggravation , that pressure distribution become a problem in this 6th example be only immersion liquid 8a filled by the up container 8 , and it can ease the effect of the immersion liquid flow of the time of wafer migration by forming the optical path L8 of this part short enough to the level which do not become a problem practically .

[0058] In addition, although the lower container 7 and the up container 8 were moved as one in this example, only the lower container 7 can be moved and the up container 8 can also be fixed. Immersion liquid 8a in the up container 8 will stop thoroughly at the time of this configuration. Therefore, among working distances L, it is desirable to form thinly enough the thickness L7 of immersion liquid 7a in the lower part [ thickness / L8 / of immersion liquid 8a in the up container 8 ] container 7.

[0059]

[Explanation of other modifications] As mentioned above, although each example of this invention was explained, as shown in previous drawing 1 , since the working distance at the time of immersion projection exposure is very as small as about 1-2mm, focusing to Wafer W shall use the focal alignment sensor FAD of an off-axis method. However, the focal detection device of the TTL (SURUZA lens) method which projects the beam for focal detection on a wafer through the periphery within the projection visual field of projection lens system PL, and measures the height location or inclination on the front face of a wafer may be established as indicated by the U.S. Pat. No. 4,801,977 number, the U.S. Pat. No. 4,383,757 number, etc., for example.

[0060] Moreover, although the focal alignment sensor FAD shown in drawing 1 shall detect the alignment mark on Wafer W optically by the off-axis method, it is good also as an alignment sensor of the TTL method which detects the mark on Wafer W other than the TTR alignment sensor 45 in drawing 1 to which this alignment sensor also detects the mark on Wafer W through Reticle R and projection lens system PL only through projection lens system PL. Furthermore, if it has the projection optical system which carries out projection exposure under an ultraviolet-rays region (wavelength of 400nm or less), this invention can completely be similarly applied, even if it is the aligner of what kind of configuration.

[0061]
[Effect of the Invention] By this invention, the aligner of an immersion type with which image formation engine performance sufficient within the limits of a realizable temperature control was guaranteed was offered as mentioned above. Moreover, the structure of a wafer stage of having been suitable for loading and unloading of a wafer in an immersion photolithography system was also offered.

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## DESCRIPTION OF DRAWINGS

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[Brief Description of the Drawings]
[Drawing 1] It is drawing showing the overall configuration of the scanning projection aligner by the 1st example of this invention.
[Drawing 2] It is a perspective view for explaining the sequence of scan exposure typically.
[Drawing 3] It is the fragmentary sectional view showing the detailed configuration near the projection lens system in drawing 1 .
[Drawing 4] It is the block diagram showing typically the temperature control and the liquid distribution system of a liquid by the 2nd example of this invention.
[Drawing 5] It is the fragmentary sectional view showing the structure the wafer electrode holder by the 3rd example of this invention, and near a projection lens system.
[Drawing 6] It is the fragmentary sectional view showing the structure the wafer electrode holder by the 4th example of this invention, and near a projection lens system.
[Drawing 7] They are the (A) sectional view showing the structure of the holder table by the 5th example of this invention, and the (B) top view.
[Drawing 8] It is the outline sectional view showing the important section of the 6th example of this invention.
[Description of Notations]
1 -- Projection optical system 1a -- The last lens side
7 Eight -- Container 7a, 8a -- Immersion liquid
3 -- Wafer 3a -- Wafer electrode holder
4 -- Inlet 5 -- Exhaust port
6 -- Temperature controller L -- Working distance
10 -- Illumination system 12 -- Condenser-lens system
14 -- Mirror 16 -- Reticle stage
17 -- Laser interferometer system 18 -- Motor
19 -- Column structure 20 -- Reticle stage controller
30 -- Base surface plate 32A, 32B, 32C -- Actuator
33 -- Laser interferometer system 34 -- X-Y stage
35 -- Wafer stage controller 36 -- Drive motor
40 -- Master controller 50A, 50B -- Heat regulator
51 -- Slot 51 52 -- Path
53 -- Pipe 53A, 53B -- Path
55 -- Thermo sensor 60 -- Controller

62 ·· Change bulb 64 ·· Liquid supply unit
64A ·· Pump 64B ·· Thermoregulator
66 ·· Drainage pump 66 80 ·· Sub lens-barrel
82 ·· ZL stage 83 ·· Pin center,large rise pin
84A, 84B ·· Flat spring 85 ·· Vertical-movement drive
87 ·· Covering plate 88A, 88B ·· Drive
90 ·· Wafer chuck 91 ·· Breakthrough
95 ·· Arm 112 ·· Piping
113 ·· Adsorption side 114 ·· Periphery corner
IL ·· Pulse illumination light A.I. Artificial Intelligence ·· Lighting field
R ·· Reticle Pa ·· Circuit pattern space
SB ·· Protection-from-light band PL ·· Projection lens system
AX ·· Optical axis LGa ·· Pre-group lens system
LGb ·· Rear group lens system Ep ·· Exit pupil
LE1 ·· Positive lens component Pe ·· Underside
CG ·· Parallel plate W ·· Wafer
SAa, SAb ·· Shot field SI ·· Projection image
WH ·· Holder table LB ·· Wall
LQ ·· Liquid HRS ·· Auxiliary plate section
DB ·· Fluid-tight door section OL ·· O ring
FAD ·· Focal alignment sensor
MRr, MRw ·· Migration mirror ML ·· Reference mirror
BSr ·· Beam for reference BSm ·· Beam for length measurement
Sf ·· Focal signal Sa ·· Alignment signal
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